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S U P P L E M E N T

TO THE THIRD EDITION OF THE

ENCYCLOPÆDIA BRITANNICA,

OR, A

D I C T I O N A R Y

OF

ARTS, SCIENCES,

AND

MISCELLANEOUS LITERATURE.

IN TWO VOLUMES.

Illustrated with Fifty Copperplates.

By GEORGE GLEIG, LL. D. F. R. S. EDIN.

NON IGNORO, QUÆ BONA SINT, FIERI MELIORA POSSE DOCTRINA, ET QUÆ NON OPTIMA,
ALIQUO MODO ACUI TAMEN, ET CORRIGI POSSE.—*CICERO.*

VOL. I.

THE SECOND EDITION, WITH IMPROVEMENTS.

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TO THE KING.

SIR,

It proceeds from no vain confidence in my own abilities, that I presume to solicit for this WORK the Protection of a MONARCH, who is not more exalted in station, than he is distinguished, among the Potentates of the Earth, by his Taste in Literature, and his Patronage of Science and the Arts.

IN conducting to its conclusion the ENCYCLOPÆDIA BRITANNICA, I am conscious only of having been uniformly influenced by a sincere desire to do Justice to those Principles of Religion, Morality, and Social Order, of which the Maintenance constitutes the Glory of Your MAJESTY'S Reign, and will, I trust, record Your Name to the latest Posterity, as the Guardian of the Laws and Liberties of Europe.

THE French Encyclopédie has been accused, and justly accused, of having disseminated, far and wide, the seeds of Anarchy and Atheism. If the ENCYCLOPÆDIA BRITANNICA shall, in any degree, counteract the tendency of that pestiferous Work, even these two Volumes will not be wholly unworthy of Your MAJESTY'S Patronage; and the Approbation of my SOVEREIGN, added to the consciousness of my own upright intentions, will, to me, be an ample reward for the many years of labour which I have employed on them, and on the Volumes to which they are Supplementary. I am,

SIR,

YOUR MAJESTY'S

Most faithful Subject,

And most devoted Servant,

*STIRLING,
Dec. 10. 1800.* }

GEORGE GLEIG.

ADVERTISEMENT.

IT would ill become me to dismiss these Volumes from my hands without acknowledging that, from many of the most valuable disquisitions which they contain, I can claim no other merit than that of having ushered them into the world.

THOSE who have read, and who understand, the articles in the Encyclopædia Britannica, which were furnished by Professor Robison of Edinburgh, can hardly need to be informed, that to the same eminent philosopher I am indebted for the valuable articles ARCH, ASTRONOMY, CARPENTRY, CENTRE, DYNAMICS, ELECTRICITY, IMPULSION, INVOLUTION and EVOLUTION of Curves, MACHINERY, MAGNETISM, MECHANICS, PERCUSSION, PIANO-FORTE, Centre of POSITION, TEMPERAMENT in Music, THUNDER, Musical TRUMPET, TSCHIRNHAUS, and WATCHWORK, in this Supplement. Of a friend and co-adjutor, whose reputation is so well established as Dr Robison's, I am proud to say, that, while I looked up to him, during the progress of this Work, as to my master in mathematical and physical science, I found him ever ready to support, with all his abilities, those great principles of religion, morality, and social order, which I felt it my own duty to maintain.

To Thomas Thomson, M. D. of Edinburgh, a man of like principles, I am indebted for the beautiful articles CHEMISTRY, MINERALOGY, and *Vegetable, Animal, and Dyeing* SUBSTANCES; of which it is needless for me to say any thing, since the Public seems to be fully satisfied that they prove their author eminently qualified to teach the science of Chemistry.

THE account of the French REVOLUTION, and of the wars which it has occasioned, has been continued in this Supplement by the same Gentlemen by whom that account was begun in the Encyclopædia; and, owing to the cause assigned in the article, probably with the same merits and the same defects.

MY thanks are due to Dr William Wright for his continued kindness in communicating much curious botanical information: and to Mr Professor Playfair of the university of Edinburgh, for lending his assistance, occasionally, in the mathematical department; and for writing one beautiful article in that science, which is noticed as his in the order of the alphabet.

IN compiling this Supplement, I have made very liberal use of the most respectable literary and scientific journals, both foreign and domestic; of all the late accounts of travels and voyages of discovery, which have obtained, or seem indeed to deserve, the regard of the Public; of different and opposite works on the French revolution, and what are emphatically called *French principles*; and even of the most approved Dictionaries, scientific and biographical. From no Dictionary, however, have I taken, without acknowledgment, any articles, except such as are floating everywhere on the surface of science, and are the property, therefore, of no living author.

AFTER

AFTER all my labour and industry, which, whatever be thought of my other merits, I am conscious have been great, no man can be more sensible than myself, that the Encyclopædia Britannica, even with the addition of this Supplement, is still imperfect. It would continue to be so, were another Supplement added to this by the most learned and laborious man on earth; for perfection seems to be incompatible with the nature of works constructed on such a plan, and embracing such a variety of subjects.

No candid reader will suppose that, by expressing myself thus, I mean to censure the plan of the Encyclopædia Britannica in particular; for, to the general excellence of that plan I have elsewhere borne my testimony, which I have yet seen no reason to retract. Experience has indeed led me to think, that it is susceptible of such improvements as would enable the principal Editor to carry the work *nearer* to perfection, even with less trouble to himself; but the purchasers of the third edition and this Supplement need not regret the want of those improvements, for they are such as few would discern, who have not paid the same attention that I have done to dictionaries of arts, sciences, and literature.

BEFORE I take leave of the reader, I must account for the omission of one or two articles (chiefly biographical) which I had given him reason to expect in these volumes. It was my intention at first to introduce into the Supplement articles on every subject which had been admitted into the Encyclopædia itself; and hence in the first supplementary volume will be found biographical sketches of men whose characters, though in some respects remarkable, have very little connection with science, arts, or literature. From this part of the original plan I was soon obliged to deviate. So many applications were made to me to insert accounts of persons who, whatever may have been their private virtues, were never heard of in the republic of letters, that I was under the necessity of excluding from the second volume the lives of *all* such as had not either been themselves eminent in literature, or in some liberal art or science, or been conspicuous as the *patrons* of science, arts, and literature, in others. Hence the omission of the life referred to from AUBIGNE in the first volume, and of one or two others to which references are made in the same way. The life of Mr James Hay Beattie of Aberdeen, whose originality of genius, ardent love of virtue, and early and extensive attainments in science and literature, raise him almost to the eminence of BARRETTIER, of whom we have so pathetic an account from the pen of Johnson, I omitted with regret; but I thought not myself authorized to publish what his father had then only distributed among a few particular friends. For the omission of the life of Soame Jenyns I can make no apology: it was the consequence of forgetfulness.

For the *errors* of these two volumes, whether typographical or of a nature more important, I have perhaps no occasion to solicit greater indulgence than will be voluntarily extended to me by a generous Public. Some errors I have corrected in this second impression, and some deficiencies I have supplied; but I was restrained by those who are now Proprietors of the Work from making any *addition* to the first volume, or any considerable *alteration* in the first part of the second. Hence the different conclusions which the reader will observe in the articles GALVANISM and TORPEDO, respecting the nature of the *Galvanic* power. Of these articles, the former was furnished by a friend, whose name I am not at liberty to publish; but whose reasonings appeared to me too worthy of attention to be either omitted or abridged, though they lead to a conclusion which facts more recently ascertained seem to set aside. These facts I felt it my duty to state to the public; and, under the title TORPEDO, I have been enabled to state them with the precision and regularity of arrangement which characterize the writings of Dr Thomson.

SUPPLEMENT

TO THE

ENCYCLOPÆDIA BRITANNICA.

A B E

Abacifcus
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Aberration.

ABACISCUS, in architecture, the same with **ABACUS**; for which, see *Encyclopædia*.

ABATIS, or **ABATTIS**, is, in military language, the name of a kind of retrenchment made of felled trees. When the emergency is sudden, the trees are merely laid lengthwise beside each other, with their branches pointed towards the enemy, to prevent his approach, whilst the trunks serve as a breastwork before those by whom the abatis is raised. When the abatis is meant for the defence of a pass or entrance, the boughs of the trees are generally stripped of their leaves and pointed; the trunks are planted in the ground; and the boughs are interwoven with each other. It is needless to add, that the closer the trees are laid or planted together, the more secure is the defence which they afford; and if, when they are planted, a small ditch be dug towards the enemy, and the earth thrown up properly against the lower part of the abatis, it will be very difficult to pass it if well defended.—*Simes's Military Guide*.

ABBREVIATION OF FRACTIONS, in arithmetic and algebra, is the reducing of them to lower terms; which is done by dividing the numerator and denominator by some number or quantity which will divide both without leaving a remainder of either.

ABERRATION, in optics (in *Encycl.*), refers the reader to the article **OPTICS**, n^o 17, 136, 173. It should have referred him to **OPTICS**, n^o 17, and 251—256.

ABERRATION of the Visual Ray, is a phenomenon, of which, though some account of it has been given in the *Encyclopædia* (see **ABERRATION**, in astronomy; and the article **ASTRONOMY**, n^o 337.), one of the most candid of our correspondents requires a fuller explanation. If such an explanation be requisite to him, it must be much more so to many others; and we know not where to find, or how to devise, one which would be more satisfactory, or more familiar, than the following by Dr Hutton.

“ This effect (says he) may be explained and familiarized by the motion of a line parallel to itself, much after the manner that the composition and resolution of forces are explained. If light have a progressive motion, let the proportion of its velocity to that of the earth in her orbit be as the line **BC** to the line **AC**; then, by the composition of these two motions, the particle of light will seem to describe the line **BA** or **DC**,

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instead of its real course **BC**; and will appear in the direction **AB** or **CD**, instead of its true direction **CB**. So that if **AB** represent a tube, carried with a parallel motion by an observer along the line **AC**, in the time that a particle of light would move over the space **BC**, the different places of the tube being **AB**, *ab*, *cd*, **CD**; and when the eye, or end of the tube, is at **A**, let a particle of light enter the other end at **B**; then when the tube is at *ab*, the particle of light will be at *e* exactly in the axis of the tube; and when the tube is at *cd*, the particle of light will arrive at *f*, still in the axis of the tube; and, lastly, when the tube arrives at **CD**, the particle of light will arrive at the eye or point **C**, and consequently will appear to come in the direction **DC** of the tube, instead of the true direction **BC**: and so on, one particle succeeding another, and forming a continued stream or ray of light in the apparent direction **DC**. So that the apparent angle made by the ray of light with the line **AE** is the angle **DCE**, instead of the true angle **BCE**; and the difference **BCD**, or **ABC**, is the quantity of the aberration.”

ABERRATION of the Planets, is equal to their geocentric motion, or, in other words, to the space which each appears to move as seen from the earth, during the time that light employs in passing from the planet to the eye of the observer. Thus the sun's aberration in longitude is constantly 20", that being the space actually moved by the earth, but apparently by the sun in 8 minutes and 7 seconds, the time in which light passes from the sun to the earth. If then the distance of any planet from the earth be known, the time which light employs in passing from the planet to the earth must likewise be known; for as the distance of the sun is to the distance of the planet, so is 8 minutes and 7 seconds to that time; and the planet's geocentric motion in that time is its aberration, whether it be in longitude, latitude, right ascension, or declination. See **ASTRONOMY** in this Supplement.

ABOAB, cesses levied, in India, under different denominations, beyond the standard rent.

ABSCISS, **ABSCISSE**, or *Abscissa*, is a part cut off from a straight line, and terminated at some certain point by an ordinate to a curve; as **AP** (fig. 2.), or **BP** (fig. 3.) The absciss may commence either at the vertex of the curve, or at any other fixed point; and it may be taken either upon the axis or upon the dia-

A

meter

Plate II.
fig. 1.

Plate II.

Abforption, meter of the curve, or upon any other line drawn in a given position. Hence there are on the same given line or diameter an infinite number of variable abfciffes, terminated all at one end by the fame fixed point. In the common parabola (fig. 4.), each ordinate PQ has but one abfcifs AP. In the ellipse or circle (fig. 2.), the ordinate has two abfciffes lying on the oppofite fides of it. In general, to each ordinate a line of the fecond kind, or a curve of the firft kind, may have two abfciffes; a line of the third order, three; a line of the fourth order, four; and fo on.

ABSORPTION, in ANATOMY and PHYSIOLOGY, has been fufficiently explained under thefe articles in the Encyclopædia; but there is another abforbing power poffeffed by different fubftances, which is worthy of attention, becaufe it is only by our knowledge of it that we can adapt our clothing to the various climates of the earth. The power to which we allude is that of different fubftances; fuch as wool, cotton, filk, and linen, to abforb or attraft moifture from the atmofphere. On this fubject the reader will find fome very inftructive experiments detailed (in Encycl.), where perhaps he may not have looked for them, under the title FLANEL.

ABSURDUM, a term made ufe of by mathematicians when they demonftrate any truth, by fhewing that its contrary is impoffible, or involves an abfurdity. Thus Euclid demonftrates the truth of the fourth propofition of the firft book of his Elements, by fhewing that its contrary implies this obvious abfurdity—"that two ftraight lines may inclofe a fpace."

This mode of demonftration is called *reduçio ad abfurdum*, and is every whit as conclufive as the direct method; becaufe the contrary of every falfehood muft be truth, and of every truth, falfehood.

The young geometrician, however, does not, we believe, feel himfelf fo perfectly fatisfied with a demonftration of this kind, as with thofe which, proceeding from a few felf-evident truths, conduçts him directly, by neceffary confequences, to the truth of the propofition to be proved. The reafon is, that he has not yet learned to diftinguifh accurately between the words *falfe* and *impoffible*, *different* and *contrary*. Many *different* assertions may be made relating to the fame thing, and yet be all true or all falfe; but it is impoffible to make two assertions directly *contrary* to each other, of which the one fhall not be true and the other falfe. Thus, "fnow is white," "fnow is cold," are different assertions relating to the fame thing, and both true; as, "fnow is black," "fnow is red," are both falfe: but let it be remembered, that of the firft and fecond, and of the third and fourth of thefe assertions, neither is directly *contrary* to the other; nor is any one of them, abftractly confidered, *impoffible*, or fuch as a blind man, who had never felt nor heard of fnow, might not believe upon ordinary testimony. But were all the men in Europe to tell a native of the interior parts of Africa that fnow is a thing at once *white and not white, cold and not cold*, the woolly-headed favage would know as well as the moft fagacious philofopher, that of thefe *contrary* assertions the one *muft be true* and the other *muft be falfe*. Juft fo it is with refpect to Euclid's fourth propofition. Had he proved its truth by fhewing that its contrary involves this propofition, that "the diagonal of a fquare is commenfurate with its fide," the fkilful geometrician would indeed have admitted the demonftration, becaufe

he knows well that the diagonal of a fquare is *not* commenfurate with its fide; but the tyro in geometry would have been no wifer than before. He knew from the beginning, that the propofition and its contrary cannot both be true; but which of them is true, and which falfe, fuch a demonftration could not have taught him, becaufe he is ignorant of the incommenfurability of the diagonal and fide of a fquare. No man, however, is ignorant, that two ftraight lines cannot inclofe a fpace; and fince Euclid fhows that the contrary of his propofition implies this abfurdity, no man of common fenfe can entertain a doubt but that the propofition itfelf muft be true.

ACCELERATED MOTION. } See (Encycl.) **ACCELERATING FORCE.** } **ACCELERATION;** and **MECHANICS,** Sect. VI.—and (this Supplement) **DYNAMICS.**

ACTION is a term which has been fufficiently explained in the Encyclopædia; but fince that article was written, queftions have been agitated refpecting *agents*, *agency*, and *açtion*, which, as they have employed fome of the moft eminent philofophers of the age, and are connected with the deareft interefts of man, are certainly entitled to notice in this place.

It is the opinion of Dr Reid, and we have adopted it (fee **METAPHYSICS**, n^o 109, &c. Encycl.), that no being can be an *agent*, or perform an *açtion*, in the proper fenfe of the word, which does not poffefs, in fome degree, the powers of will and underftanding. If this opinion be juft, it is obvious, that what are called the powers of nature, fuch as *impulfe*, *attraçtion*, *repulñion*, *elafticity*, &c. are not, ftrictly fpeaking, *powers* or *caufes*, but the effects of the agency of fome active and intelligent being; and that *physical caufes*, to make ufe of common language, are nothing more than *laws* or *rules*, according to which the *agent* produces the effect.

This doctrine has been controverted by a writer whofe acutenefs is equalled only by his virtues; and we fhall confider fome of his objections to it in another place (fee **CAUSE**): but a queftion of a different kind falls under our prefent confideration; and perhaps the answer which we muft give to it, may go far to remove the objections to which we allude.

Can an agent operate where, either by itfelf or by an inftrument, it is not prefent? We think not; becaufe agency, or the exertion of power, muft be the agency of fomething. The confitution of the human mind compels us to attribute every açtion to fome *being*; but if a being could aät in *one* place from which it is abfent, it might do the fame in a fecond, in a third, and in all places; and thus we fhould have açtion without an agent: for to be abfent from all places is a phrafe of the fame import as not to exift. But if a living and intelligent being cannot aät but where it is either immediately or inftrumentally prefent, much lefs furely can we attribute events of any kind to the agency of an abfent and inanimated body. Yet it has been faid, that "we have every reafon, which the nature of the fubject and of our own faculties can admit of, to believe, that there are among things inanimate fuch relations, that they may be mutually caufes or principles of change to one another, without any exertion of *power*, or any operation of an agent, ftrictly fo called. Such relations, for aught that we know, may take place among bodies at great diftances from one another, as well as among bodies

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Action.

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Action. bodies really or seemingly in actual contact; and they may vary both in degree and in kind, according to the distances between the bodies."

That any thing should be a cause or principle of change to another, without the exertion of *power* or the operation of an agent, appears to us a palpable contradiction; and we could as easily conceive any two sides of a triangle to be not greater than the third side, as reconcile such a proposition to that faculty of our minds by which we distinguish truth from falsehood. When we see one body the apparent cause of change in another body, we cannot possibly entertain a doubt of the *exertion of power*; but whether that power be in the body apparently producing the change, or in a distinct agent, is a question to which an answer will not so readily be found. That it is in a distinct agent, we are strongly inclined to believe, not only by the received doctrine concerning the inertia of matter, which, though it has been frequently controverted, we have never seen disproved, but much more by considering the import of an observation frequently introduced to prove the direct contrary of our belief. "We cannot be charged (says the writer whom we have just quoted) with maintaining the absurdity, that there may be an effect without a cause, when we refer the fall of a stone to the ground, and the ebbing and flowing of the sea, to the *influence* of the earth on the stone, and of the sun and moon on the ocean, according to the principle of general gravitation."

We admit the truth of this observation, provided the influence of the sun and moon on the ocean be possible; but, to us at least, it appears impossible, and is certainly inconceivable. The influence of the sun and moon can here mean nothing but the *action* or *operation* of the sun and moon; but if these two bodies be inanimate, they cannot *act* at all, in the proper sense of the word; and whatever they be, it is obvious that they cannot *act immediately* on an object at such a distance from them as the earth and the ocean. If they be the agents, they must operate by an instrument, as we do when moving objects to which our hands cannot reach; but as it has been shewn elsewhere (see *METAPHYSICS*, n° 199. and *OPTICS*, n° 63. *Encycl.*); that neither air nor æther, nor any other material instrument which has yet been thought of, is sufficient to account for the phenomena of attraction and repulsion, it is surely much more rational to conclude, that the ebbing and flowing of the sea are produced, not by the influence of the sun and moon, but by the power of some distinct agent or agents.

What those agents are, we pretend not to say. If the Supreme Being himself be the immediate author of every change which takes place in the corporeal world, it is obvious that he acts by fixed rules, of which many are apparent to the most heedless observer, whilst the discovery of others is reserved for the reward of the judicious application of the faculties which he has given us. If he employs inferior agents to carry on the great operations of nature, it is surely not difficult to conceive that the powers of those agents which were derived from him, may by him be restrained within certain limits, and their exercise regulated by determined laws, in such a manner as to make them produce the greatest benefit to the whole creation. Nor let it be thought an objection to this theory, that the changes

which take place among bodies at great distances from each other, vary both in degree and in kind according to the distances; for this variation, which we acknowledge to be a fact, appears to us wholly unaccountable upon any other hypothesis than that which attributes the different changes to agents distinct from the bodies themselves. Did we perceive all the particles of matter, at all distances, tending towards each other by a fixed law, we might be led to consider mutual attraction as an *essential* property of that substance, and think no more of inquiring into its cause, than we think of inquiring into the cause of extension. But when we find that the same particles, which at one distance seem to attract each other, are at a different distance kept asunder by a power of repulsion, which no force, with which we are acquainted, is able to overcome, we cannot attribute the *principle* or *cause* of these changes to brute matter, but must refer it to some other agent exerting power according to a fixed law.

It is the fashion at present to despise all metaphysical inquiries as abstruse and useless: and on this account we doubt not but some of our readers will turn away from this disquisition with affected disgust, whilst the petulant and unthinking chemist, proud of possessing the secrets of his science, will deem it superfluous to inquire after any other natural agents than those of which he has been accustomed to talk. But with the utmost respect for the discoveries made by modern chemists, which we acknowledge to be both numerous and important, we beg leave to observe, that though these gentlemen have brought to light many events and operations of nature formerly unknown, and have shown that those operations are carried on by established laws, none of them can say with certainty that he has discovered a single agent. The most enlightened of them indeed pretend not to have discovered in one department of science more than Newton discovered in another; for they well know that agents and agency cannot be subjected to any kind of physical experiments. Our very notions of these things are derived wholly from our own consciousness and reflection; and when it is considered what dreadful consequences have in another country resulted from that pretended philosophy which excludes the agency of mind from the universe, it is surely time to inquire whether our consciousness and reflection do not lead us to refer real agency to mind alone. Let this be our apology both to the real and to the affected enemies of metaphysics for endeavouring to draw their attention to the present question. It is a question of the utmost importance, as well to science as to religion: and if the laws of human thought decide it, as we have endeavoured to show that they do, we may without hesitation affirm, that the impious philosophy of France can never gain ground but among men incapable of patient thinking.

ADAMAS, a name given, in astrology, to the moon.

ÆOLUS, in mechanics, a small machine invented by Mr Tidd for refreshing or changing the air in rooms when it becomes too hot or otherwise unfit for respiration. The æolus is so contrived as to supply the place of a square of glass in the window, where it works, with very little noise, like the sails of a wind-mill or a smoke-jack.

AEROLOGY is a branch of science which was de-
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Afghans. tailed in the Encyclopædia at sufficient length, and according to the principles which were then generally admitted by chemists. Subsequent experiments, however, have shown, that some of those principles are erroneous, and of course that some of the opinions advanced in the article **AEROLOGY** are inconsistent with facts. These opinions must be corrected; but instead of swelling this volume with a new article **AEROLOGY**, we apprehend that it will be more acceptable to our scientific readers to refer them for those corrections to the article **CHEMISTRY** in this Supplement.

AFGHANS, are a people in India who inhabit a province of **CABUL** or **CABULISTAN** (see *Encycl.*), and have always been connected with the kingdoms of Persia and Hindostan. They boast of being descended of Saul the first king of Israel; of whose advancement to the royal dignity they give an account which deviates not very widely from the truth. They say indeed, that their great ancestor was raised from the rank of a shepherd, not for any princely qualities which he possessed, but because his stature was exactly equal to the length of a rod which the angel Gabriel had given to the prophet Samuel as the measure of the stature of him whom God had destined to fill the throne of Israel.

SAUL, whose descent, according to some of them, was of Judah, and according to others of Benjamin, had, they say, two sons, **BERKIA** and **IRMA**, who served David, and was beloved by him. The sons of Berkia and Irmia were **AFGHAN** and **USBEC**, who, during the reigns of David and Solomon, distinguished themselves, the one for his corporeal strength, and the other for his learning. So great indeed was the strength of *Afghan*, that we are told it struck terror even into demons and genii.

This hero used frequently to make excursions to the mountains, where his progeny, after his death, established themselves, lived in a state of independence, built forts, and exterminated infidels. When the select of creatures (the appellation which this people give to *Mahomet*) appeared upon earth, his fame reached the *Afghans*, who sought him in multitudes under their leaders *Khalid* and *Abdul Respid*, sons of *Walid*; and the prophet honouring them with this reception—"Come, O *Muluc*, or Kings!" they assumed the title of *Melic*, which they retain to this day.

The history, from which this abstract is taken, gives a long and uninteresting detail of the exploits of the *Afghans*, and of their zeal in overthrowing the temples of idols. It boasts of the following monarchs of their race who have sat upon the throne of *Debli*: Sultan **BEHLOLE**, *Afghan Lodi*, Sultan **SECANDER**, Sultan **IRBAHIM**, **SHIR SHAH**, **ISLAM SHAH**, **ADIL SHAH SUR**. It also numbers the following kings of *Gaur* descended of the *Afghan* chiefs: **SOLAIMAN Shah Gurzani**, **BEYAZID Shah**, and **KUTB Shah**; besides whom, their nation, we are told, has produced many conquerors of provinces. The *Afghans* are sometimes called *Solaimani*, either because they were formerly the subjects of **SOLOMON** king of Israel, or because they inhabit the mountains of Solomon. They are likewise called **PATANS**, a name derived from the *Hindi* verb *Paitna* "to rush," which was given to them by one of the Sultans whom they served, in consequence of the alacrity with which they had attacked and conquered his enemies. The province which they occupy at present was for-

merly called *Rob*; and hence is derived the name of the *Robillas*. The city which was established in it by the *Afghans* was called by them *Paishower* or *Paisber*, and is now the name of the whole district. The sects of the *Afghans* are very numerous; of which the principal are, *Lodi*, *Lobouni*, *Sur*, *Serwani*, *Yusufzibi*, *Bangish*, *Dilazai*, *Khetti*, *Yafin*, *Kail*, and *Beleje*. They are *Musulmans*, partly of the *Sunni*, and partly of the *Shiek* persuasion.

Though they are great boasters, as we have seen, of the antiquity of their origin, and the reputation of their race, other *Musulmans* reject their claim, and consider them as of modern, and even of base, extraction.

This is probably a calumny; for it seems inconsistent with their attention to the purity of their descent—an attention which would hardly be paid by a people not convinced of their own antiquity. They are divided into four classes. The first is the *pure* class, consisting of those whose fathers and mothers were *Afghans*. The second class consists of those whose fathers were *Afghans* and mothers of another nation. The third class contains those whose mothers were *Afghans* and fathers of another nation. The fourth class is composed of the children of women whose mothers were *Afghans* and fathers and husbands of a different nation. Persons who do not belong to one of these classes are not called *Afghans*.

This people have at all times distinguished themselves by their courage, both singly and unitedly, as principals and auxiliaries. They have conquered for their own princes and for foreigners, and have always been considered as the main strength of the army in which they served. As they have been applauded for virtues, they have also been reproached for vices, having sometimes been guilty of treachery, and of acting the base part even of assassins.

Such is the account of the *Afghans* published in the second volume of the *Asiatic Researches*. It was translated from a Persian abridgment of a book written in the *Pushto* language, and called *The Secrets of the Afghans*, and communicated by Henry Vansittart, Esq; to Sir William Jones, then president of the *Asiatic Society*. Their claim to a descent from Saul king of Israel, whom they call **MELIC TALUT**, is probably of not a very ancient date; for the introduction of the angel Gabriel with his rod, gives to the whole story the air of one of those many fictions which *Mahomet* borrowed from the later rabbins. Sir William Jones, however, though he surely gave no credit to this fable, seems to have had no doubt but the *Afghans* are descendants of Israel. "We learn (says he) from **ESDRAS**, that the ten tribes, after a wandering journey, came to a country called *Arsareth*, where we may suppose they settled: now the *Afghans* are said by the best *Persian* historians to be descended from the *Jews*. They have traditions among themselves of such a descent; and it is even asserted, that their families are distinguished by the names of *Jewish* tribes, although since their conversion to *Islam*, they studiously conceal their origin from all whom they admit not to their secrets. The *Pushto* language, of which I have seen a dictionary, has a manifest resemblance to the *Chaldaick*; and a considerable district under their dominion is called *Hazareth* or *Hazaret*, which might easily have been changed into the word used by **ESDRAS**. I strongly recommend an inquiry into the literature and history of the *Afghans*."

Albategni
||
Almamon.

It is to co-operate with this accomplished scholar that we have inserted into our Work this short account of that singular people; and it is with pleasure that, upon the authority of Mr Vanfittart, we can add, that a very particular account of the *Afghans* has been written by the late HAFIZ RAHMAT *Khan*, a chief of the *Robillabs*, from which such of our readers as are oriental scholars may derive much curious information.

ALBATEGNI, an Arabic prince of Batan in Mesopotamia, was a celebrated astronomer, about the year of Christ 880, as appears by his observations. He is also called *Muhammed ben Geber Albatani*, *Mabomet the son of Geber*, and *Muhamedes Araënsis*. He made astronomical observations at Antioch, and at Racah or Aracta, a town of Chaldea, which some authors call a town of Syria or of Mesopotamia. He is highly spoken of by Dr Halley, as *vir admirandi acuminis, ac in administrandis observationibus exercitissimus*.

Finding that the tables of Ptolemy were imperfect, he computed new ones, which were long used as the best among the Arabs: these were adapted to the meridian of Aracta or Racah. Albategni composed in Arabic a work under the title of *The Science of the Stars*, comprising all parts of astronomy, according to his own observations and those of Ptolemy. This work, translated into Latin by Plato of Tibur, was published at Nuremberg in 1537, with some additions and demonstrations of Regiomontanus; and the same was reprinted at Bologna in 1645, with this author's notes. Dr Halley detected many faults in these editions.—*Phil. Transf.* for 1693, N^o 204.

In this work Albategni gives the motion of the sun's apogee since Ptolemy's time, as well as the motion of the stars, which he makes one degree in 70 years. He made the longitude of the first star of Aries to be 18° 2'; and the obliquity of the ecliptic 23° 35'. And upon Albategni's observations were founded the Alphonsine tables of the moon's motions; as is observed by Nic. Muler, in the *Tab. Frisica*, p. 248.

ALDERAIMIN, a star of the third magnitude, in the right shoulder of the constellation Cepheus.

ALFRAGAN, ALFERGANI, or *Fargani*, a celebrated Arabic astronomer, who flourished about the year 800. He was so called from the place of his nativity, Fergan, in Sogdiana, now called Maracanda, or Samarcand, anciently a part of Bactria. He is also called *Ahmed* (or *Muhammed*) *ben-Cothair*, or *Katir*. He wrote the *Elements of Astronomy* in 30 chapters or sections. In this work the author chiefly follows Ptolemy, using the same hypothesis, and the same terms, and frequently citing him. Of Alfragan's work there are three Latin translations, of which the last and best was made by Golius, professor of mathematics and oriental languages in the university of Leyden. This translation, which was published in 1669, after the death of Golius, is accompanied with the Arabic text, and with many learned notes on the first nine chapters, which would undoubtedly have been carried to the end, had the translator lived to complete his plan.

ALGORAB, a fixed star of the third magnitude, in the right wing of the constellation Corvus.

ALHAZEN, an Arabian astronomer, who flourished in Spain about the beginning of the 12th century. See ASTRONOMY, n^o 6. *Encycl.*

ALMAMON, was a philosopher and astronomer,

who, in the beginning of the 9th century, ascended the throne of the caliphs of Bagdat. He was the son of Harun Al-Rasheed, and grandson of Almanfor. His name is otherwise written *Mamon*, *Almaon*, *Almamun*, *Alamoun*, or *Al-Maimon*. Having been educated with great care, and with a love for the liberal sciences, he applied himself to cultivate and encourage them in his own country. For this purpose he requested the Greck emperors to supply him with such books on philosophy as they had among them; and he collected skilful interpreters to translate them into the Arabic language. He also encouraged his subjects to study them; frequenting the meetings of the learned, and assisting at their exercises and deliberations. He caused Ptolemy's *Almagest* to be translated in 827, by Isaac Ben-honain, and Thabet Ben-korah, according to Herbelot, but, according to others, by Sergius, and Alhazen the son of Joseph. In his reign, and doubtless by his encouragement, an astronomer of Bagdat, named Habash, composed three sets of astronomical tables.

Almamon himself made many astronomical observations, and determined the obliquity of the ecliptic to be then 23° 35' (or 23° 33' in some manuscripts), but Vossius says 23° 51' or 23° 34'. He also caused skilful observers to procure proper instruments to be made, and to exercise themselves in astronomical observations; which they did accordingly at Shemasi in the province of Bagdat, and upon Mount Casius near Damus.

Under the auspices of Almamon also a degree of the meridian was measured on the plains of Sinjar or Singiar (or, according to some, Fingar), upon the borders of the Red Sea; by which the degree was found to contain 56½ miles, of 4000 coudees each, the coudee being a foot and a half: but it is not known what foot is here meant, whether the Roman, the Alexandrian, or some other. Riccioli makes this measure of the degree amount to 81 ancient Roman miles, which value answers to 62,046 French toises; a quantity more than the true value of the degree by almost one-third. Finally, Almamon revived the sciences in the East to such a degree, that many learned men were found, not only in his own time, but after him, in a country where the study of the sciences had been long forgotten. This learned king died near Tarsus in Cilicia, by having eaten too freely of some dates, on his return from a military expedition, in the year 833.

ALOE DICHOtOMA, in botany, called by the Dutch *Kooker-boom* or *Quiver tree*, is a native of the southern parts of Africa, and seems to be a species of the AGAVE or *American aloe* (see AGAVE, *Encycl.*) It is thus described by LE VAILLANT in his *New Travels into the Interior Parts of Africa*: "The *aloe dichotoma* rises to the height of 25 or 30 feet; its trunk is smooth, and the bark white. When young, and the trunk not more than four or five feet long, it terminates with a single tuft of leaves, which, like those of the ananas, spread and form a crown, from the midst of which all its flowers issue. As it grows older, it pushes out lateral branches, perfectly regular and symmetrical, each of which has at its extremity a crown similar to that of the young plant. The *kooker-boom* thrives much better on mountains than in the plain. Instead of long roots penetrating deep into the earth, like those of other trees, it has but a very slight one by which it is fixed to the soil. Accordingly, three inches of mould are sufficient

Almamon,
Aloc.

Alce.
Alphonfus.

sufficient to enable it to grow upon the very rocks, and attain its utmost beauty; but its root is so feeble a support, that I could throw down the largest with a single kick of my foot. The hordes on the west make their quivers of the trunk of this tree when young, whence is derived the name given it by the planters."

It becomes not us, sitting in our chamber, to controvert a fact in natural history, of the reality of which we never had an opportunity of judging; nor would it be proper, on account of our own scepticism, to suppress the narrative of a traveller, who corrects the narratives of former travellers in terms which nothing should have dictated but the consciousness of his own invariable veracity. Yet we hope to be pardoned for expressing our surprise that, in any part of the world, trees should be found in great numbers 25 or 30 feet high, and shooting out many branches, which have yet to loose a hold of the ground, that the largest of them may be thrown down by the single kick of a man's foot. The reader's surprise will probably equal our's, when he is informed that the author saw one of these trees of which the trunk was ten feet four inches in circumference, whilst its branches overshadowed a space of more than 100 feet in diameter! This tree he assures that he could have kicked over. The country, according to his account, is not exempted from storms. He is himself a French philosopher. What a pity then is it that he did not explain to those, who have not had the benefit of being enlightened in that school, upon what principle of mechanics or statics the tree could resist the violence of the elements till it arrived at so enormous a size?

ALPHONSUS X king of Leon and Castile (see *Encycl.*) This prince understood astronomy, philosophy, and history, as if he had been only a man of letters; and composed books upon the motions of the heavens, and on the history of Spain, which are highly commended. "What can be more surprising (says Mariana), than that a prince, educated in a camp, and handling arms from his childhood, should have such a knowledge of the stars, of philosophy, and the transactions of the world, as men of leisure can scarcely acquire in their retirements? There are extant some books of Alphonfus on the motions of the stars, and the history of Spain, written with great skill and incredible care." In his astronomical pursuits he discovered that the tables of Ptolemy were full of errors; and thence he conceived the first of any the resolution of correcting them. For this purpose, about the year 1240, and during the life of his father, he assembled at Toledo the most skilful astronomers of his time, Christians, Moors, and Jews, when a plan was formed for constructing new tables. This task was accomplished about 1252, the first year of his reign; the tables being drawn up chiefly by the skill and pains of Rabbi Isaac Hazan, a learned Jew, and the work called the *Alphonfian Tables*, in honour of the prince, who was at vast expences concerning them. He fixed the epoch of the tables to the 30th of May 1252, being the day of his accession to the throne. They were printed for the first time in 1483, at Venice, by Radtoldt, who excelled in printing at that time. This edition is extremely rare: there are others of 1492, 1521, 1545, &c.

In the Encyclopædia it is said, that the charge of impiety brought against this prince was *unjust*. This was said too confidently, because we know not of any

direct proof of his innocence. All that has been said for him by Dr Hutton, one of his ablest apologists, amounts to nothing more than a high degree of probability that the charge was carried by much too far. The charge itself was, that Alphonfus affirmed, "that if he had been of God's privy-council when he made the world, he would have advised him better." Mariana, however, says only in general, that Alphonfus was so bold as to blame the works of Providence, and the construction of our bodies; and he says that this story concerning him rested only upon a vulgar tradition. The Jesuit's words are curious: "Emanuel, the uncle of Sanchez (the son of Alphonfus), in his own name, and in the name of other nobles, deprived Alphonfus of his kingdom by a public sentence; which that prince merited, for daring severely and boldly to censure the works of Divine Providence, and the construction of the human body, as tradition says he did. Heaven most justly punished the folly of his tongue." Though the silence of such an historian as Mariana, in regard to Ptolemy's system, ought to be of some weight, yet we cannot think it improbable, that if Alphonfus did pass so bold a censure on any part of the universe, it was on the celestial sphere, and meant to glance upon the contrivers and supporters of that system. For, besides that he studied nothing more, it is certain that at that time astronomers explained the motions of the heavens by intricate and confused hypotheses, which did no honour to God, nor anywise answered the idea of an able workman. So that, from considering the multitude of spheres composing the system of Ptolemy, and those numerous eccentric cycles and epicycles with which it is embarrassed, if we suppose Alphonfus to have said, "that if God had asked his advice when he made the world, he would have given him better counsel," the boldness and impiety of the censure will be greatly diminished.

Such is the apology made by Dr Hutton for this royal astronomer of Spain; and we hope, for the honour of science, that it is well founded. Still it leaves Alphonfus guilty of great irreverence of language, which is to us wholly unaccountable, if it be really true that he read the Bible fourteen times. We have seen impiety indeed break out lately from very eminent astronomers of a neighbouring nation; but these men read not the Bible, nor any thing else, but the dreams of the eternal sleepers.

ALTERNATE ANGLES. See GEOMETRY (*Encycl.*), Part I. 25.

ALTERNATE Ratio, or Proportion, is the ratio of the one antecedent to the other, or of one consequent to the other, in any proportion, in which the quantities are of the same kind. So if $A : B :: C : D$, then alternately, or by alternation $A : C :: B : D$.

ALTITUDE, PARALLAX OF, is an arch of a vertical circle, by which the true altitude, observed at the centre of the earth, exceeds that which is observed on the surface. See PARALLAX (*Encycl.*) and ASTRONOMY (*Suppl.*)

ALTITUDE of the Nonagesimal, is the altitude of the 90th degree of the ecliptic, counted upon it from where it cuts the horizon, or of the middle or highest point of it which is above the horizon, at any time; and is equal to the angle made by the ecliptic and horizon where they intersect at that time.

Alphonfus
Altitude.

Alitude,
Alum.

ASTITUDE of the Cone of the Earth's or Moon's Shadow, the height of the shadow of the body made by the sun, and measured from the centre of the body. To find it say, As the tangent of the angle of the sun's apparent semidiameter is to radius; so is 1 to a fourth proportional, which will be the height of the shadow in semidiameters of the body.

ALUM is a salt so useful in commerce and the arts, that the knowledge of its component parts, and of the best method of preparing it, must be of importance. In the article CHEMISTRY (Encycl.), the opinions which were then held respecting its composition, and the practice which was generally followed in its preparation, have been detailed at full length; but some of these opinions have since been controverted, and if they be erroneous, it must be expedient to vary in some degree the mode of preparation. In particular, the opinion that it is merely an excess of acid which prevents the formation of alum by evaporation of the ley, has been shown to be false by Citizen *Vauquelin*, who contends, of course, that the addition of putrid urine to the ley is a very bad practice.

This eminent chemist had long suspected, that the crystallization of alum is not prevented by an excess of acid, and that pot-ash is not of use simply to saturate this acid, but to perform an office of more importance. To bring his suspicions to the test of experiment, he dissolved very pure ALUMINE in sulphuric acid of equal purity, and evaporated the solution to dryness, for the purpose of expelling the superabundant acid. He then redissolved the dry and pulverulent residuum in water, and reduced the solution to different degrees of specific gravity, with a view to seize the point most favourable to crystallization; but with every possible precaution he could obtain nothing but a magma (see MAGMA), formed of saline plates, without consistence or solidity. This solution, however, though it constantly refused to afford crystallized alum alone, afforded it immediately by the addition of a few drops of the solution of pot-ash; and as he had employed these two substances in the requisite proportion, the rest of the solution, to the very end, afforded pure alum, without any mixture of sulphat of pot-ash.

Into another portion of the same solution of pure alumine, he dropped the same quantity of carbonate of soda as he had added of that of pot-ash to the former; but no crystallization was formed, even by the help of evaporation, nor did lime and barytes produce any better effect. But if the common opinion that pot-ash, in the formation of alum, is of use only to abstract the excess of acid, be true, soda, lime, barytes, and all the substances which by a more powerful force would take this acid from alum, ought to give the same result. Another argument presented itself, which seemed decisive: If the alkalies, pot-ash, and ammoniac, do nothing more than unite to the superabundant acid of the alum, the sulphats of pot-ash and of ammoniac ought not to occasion any change in pure alum in its acidulated state; whereas if these alkalies enter as a constituent part into the alum, and are necessary to its existence,

they ought to produce the same effects as pure pot-ash or ammoniac. He therefore added to a third portion of the solution of sulphat of alumine before-mentioned some drops of the solution of sulphat of pot-ash; immediately upon which octahedral crystals of alum were formed. The sulphat of ammoniac presented the same effect.

This result gave still greater confirmation to his first notions, though it did not yet afford a demonstration perfectly without objection; for it might have happened that the two salts he made use of might determine the crystallization of the alum, simply by absorbing the superfluous acid, of which they are very greedy; but to determine this possible fact, he mixed in the uncrystallizable solution of alumine some sulphat of pot-ash with excess of acid, and obtained a crystallization no less abundant than with the neutral sulphat of pot-ash.

This last experiment leaves therefore no doubt with regard to the influence and mode of action of pot-ash and ammoniac in the fabrication of alum; and this action is still more strongly confirmed by the examination of the alums which have been formed by the processes above related; for in this manner it is proved that they contain considerable quantities of the sulphats of pot-ash and ammoniac.

These experiments led M. *Vauquelin* to an examination of the different alums of commerce, of which he found not one that did not afford sulphat of pot-ash, or of ammoniac, or of both. His methods of analysis are very accurate; but to detail them at length would swell this article to little purpose. To such of our readers as are not chemists they would hardly be intelligible; and the experienced chemist will devise methods of analysis for himself. It may be proper, however, to observe, that M. *Vauquelin* proved, to his own satisfaction, that the sulphat of pot-ash, or of ammoniac, is necessary to render alum capable of being precipitated by its earth, or to cause it to pass, as it were, to the earthy state (A). He proved likewise, that such aluminous waters as do not contain pot-ash, may remain, as long as may be desired, on their materials, without being saturated with too great a quantity of earth, or suffering alum to precipitate.

From the whole of his experiments our author drew the following conclusions, which he considers as of importance to the arts, to chemistry, and to natural history.

1. It is not, at least in the greatest number of circumstances, the excess of acid which impedes the crystallization of alum, but it is the want of pot-ash or ammoniac: For it is difficult to imagine that the sulphuric acid could remain disengaged after so long remaining upon alumine in a state of extreme division, and always superabundant. It is true that the aluminous waters redden the vegetable tinctures; but this property is not owing to a disengaged acid. This portion of acid is a constituent part of these waters; and it appears to have more affinity with the neutral sulphat of alumine than with a new quantity of this earth at the temperature of the atmosphere.

2. The sulphat of pot-ash may be used, as well as pure pot-ash, to cause the crystallization of alum. It even,

(A) It may be proper to notice, that *Scheele* seems to have known this long before, and that he mentions it expressly in his paper on *Pyrophorus*.

Alum.

even has the advantage over the latter salt, because if the aluminous waters do not really contain a disengaged acid, the pot-ash, in its combination, will precipitate a portion of alumine, and diminish the product of the boiling; whereas the sulphat of pot-ash does not produce the same effect; but if the lixiviums contain disengaged acid, which must very seldom be the case, it is not converted into alum by the sulphat of pot-ash, and is lost with regard to the product. Our author therefore is of opinion, that when the waters really contain an excess of acid, or a very oxidized sulphat of iron, the use of pot-ash is preferable to that of the sulphat of pot-ash. But when economy is an object, that in many places it would be profitable to use the sulphat of pot-ash; because it is a salt indirectly produced in many manufactories, where of course it may be obtained for nothing. In particular, the residues of the distillation of aquafortis by the sulphuric acid would be excellent for this operation, and much preferable to putrid urine, because this fluid always contains phosphoric salts, which decompose a portion of the sulphat of alumine, and considerably diminish the product.

3. Alumine cannot be used in the treatment of mother waters, as Bergman proposes. This earth is incapable of favouring the crystallization of alum, besides which, it decomposes a portion of alum by the assistance of ebullition; in which circumstance it seizes the acid necessary to its solution, and precipitates it in the form of that powder which is called alum saturated with its earth.

4. Many alum ores must naturally contain pot-ash, because perfect alum is often obtained from the first crystallization of new alum waters without the addition of this alkali. It is true that an objection may be made with regard to the wood used in calcining these ores, which may be supposed to have furnished the alkali; but it is not probable that the small quantity of wood employed, in comparison to the quantity of ore and the alum it affords, could supply enough of pot-ash for the crystallization.

5. All the earths and stones which have given, or shall hereafter afford, by analysis with the sulphuric acid, perfect alum without addition of pot-ash, must contain this alkali naturally. For it is well proved, that alum cannot exist without pot-ash or ammoniac; and as there is little probability that this salt should be found combined in earths or stones, unless perhaps in very rare cases, we may almost constantly be assured, when alum is obtained from any of these substances, that its formation was effected by pot-ash. The quantity of alum will immediately show in what proportion this alkali existed in the substances analysed.

6. The alum of commerce ought not to be considered as a simple salt, but as a combination in the state of a triple and sometimes quadruple salt of sulphat of alumine, sulphat of pot-ash, or of ammoniac. Among these last we may distinguish two species; the one without excess of acid, insoluble in water and insipid, being what is improperly called alum saturated with its own earth; and the other, which contains an excess of acid soluble in water, very sapid and astringent, is the common alum.

There is likewise a pure sulphat of alumine, very astringent, very difficult of crystallization, in the form of brilliant pearl-coloured plates without consistence,

and which cannot be rendered insoluble by the addition of a new quantity of its base. This last salt may with the greatest propriety be called the sulphat of alumine.

7. It follows from the comparative analysis, and the knowledge acquired respecting the different states of the combination of alumine with the sulphuric acid united at the same time with other bases, that we must distinguish seven states in this combination, and that it is necessary to express them according to the rules of the methodical nomenclature. Here follow the series, the nature, and the names of these seven sulphats of alumine.

1. Sulphat of alumine, or the artificial combination of sulphuric acid and alumine. This salt is astringent; it crystallizes in laminæ or flexible leaves, soluble in water. It has never been described nor named by chemists. 2. Acid sulphat of alumine is the foregoing salt, with excess of acid, from which it differs by reddening blue vegetable colours. It is easily made by dissolving that salt in the sulphuric acid, but it is not easy to convert this into the neutral sulphat of alumine but by boiling it a long time with its earth. This salt, like the first, has not been described. 3. Saturated sulphat of alumine and of pot-ash is the alum of the chemists saturated with its earth. It is pulverulent, insipid, insoluble, not crystallizable, and is easily converted into true alum by the addition of sulphuric acid. 4. The acid sulphat of alumine and of pot-ash greatly resembles common alum, and is easily prepared chemically; but M. Vauquelin found no alum but that of La Tolfa, which is exactly of the same nature with it. 5. The acid sulphat of alumine and of ammoniac has all the properties of alum, and may be used for the same purposes; but though it is easily made in the laboratories, our author never found it pure in commerce. 6. The acid sulphat of alumine, pot-ash, and ammoniac. It is remarkable enough, says M. Vauquelin, that this should be the nature of the alum most frequently made in the arts, and that to express its combination so many words should be necessary. This, however, may be avoided, by reserving the name of alum to this substance, which will be sufficient to distinguish it perfectly. 7. The acidulous sulphat of alumine and of pot-ash, our author says, he is less acquainted with than with the preceding series. The name by which he characterizes it was suggested to him, and he thinks it proper, because by adding to the solution a small quantity of pot-ash more than is necessary to obtain octahedral crystals, it manifestly passes to the cubic form.

From these deductions, the physician, the chemist, and the manufacturer, with whom the uses of alum are greatly multiplied, will hereafter possess a knowledge of the substance they employ, and may appreciate its effects on the animal economy, and other bodies to which it is so frequently applied. See *Annales de Chimie*, xxii. 258, and *Nicholson's Journal*, Vol. I. p. 318, &c.

ALUMINE, one of the simple earths. See CHEMISTRY in this Supplement.

AMICABLE NUMBERS have been defined, and the first pair of them given in the Encyclopædia. The second pair of amicable numbers are 17296 and 18416; and the third pair are 9363584 and 9437056.

Dr Hutton informs us, that these three pairs of amicable numbers, with the properties from which they receive

Alum
||
Amicable.

Amicable,
Amster-
dam.

ceive their name, were found out by F. Schooten, as appears from Sect. ix. of his *Exercitationes Mathematicæ*. To find the first pair, he puts $4x$ and $4yz$, or a^2x and a^2yz for the two numbers, where $a=2$; then making each of these equal to the sum of the aliquot parts of the other, gives two equations, from which are found the values of x and z , and consequently, assuming a proper value for y , the two amicable numbers themselves $4x$ and $4yz$.

In like manner for the other pairs of such numbers; in which he finds it necessary to assume $16x$ and $16yz$, or a^4x and a^4yz for the second pair, and $128x$ and $128yz$ or a^7x and a^7yz for the third pair.

Schooten then gives this practical rule, from Descartes, for finding amicable rules, viz. assume the number 2, or some power of the number 2, such that if unity or 1 be subtracted from each of these three following quantities, viz. from 3 times the assumed number, also from 6 times the assumed number, and from 18 times the square of the assumed number, the three remainders may be all prime numbers; then the last prime number being multiplied by double the assumed number, the product will be one of the amicable numbers sought, and the sum of its aliquot parts will be the other. That is, if a be put = the number 2, and n some integer number, such that $3a^n - 1$, and $6a^n - 1$, and $18a^{2n} - 1$ be all three prime numbers; then is $18a^{2n} - 1 \times 2a^n$ one of the amicable numbers; and the sum of its aliquot parts is the other.

AMSTERDAM and ST PAUL, are two islands in the South Sea, lying in the same degree of longitude, and generally confounded with each other. The Dutch navigators have given the name of *Amsterdam* to the northern, and of *St Paul* to the southern island, and Captain Cook conforms to that appellation. Most other English navigators, and particularly Messrs Cox and Mortimer, with Sir George Staunton, reverse the names, calling the southern island Amsterdam, and the other St Paul. At this southern island the Lion man of war stopped on her voyage to China with Lord Macartney, the late ambassador to the court of Pekin, which gave an opportunity to the men of science in the train of the ambassador to examine the island with more skill and attention than probably it had ever been examined before.

Dr Gillan, who was appointed physician to the embassy, as well for his knowledge of chemistry as for his medical skill, is confident that the island of Amsterdam is the product of subterraneous fire, as it bears in every part of it evident marks of volcanic eruption. "On the west and south-west sides (says he) there are four small cones regularly formed, with craters in their centres, in which the lava and other volcanic substances have every appearance of recent formation. The heat continues still so great, and such a quantity of elastic vapours issues through numberless crevices, that there can be no doubt of their having been very lately in a state of eruption. In a thermometer placed upon the surface, the quicksilver rose constantly to 180 degrees, and when sunk a little into the ashes, it advanced to 212 degrees. It certainly would have risen still higher; but the scale being graduated only to the point of boiling water, and the length of the tube proportioned to that extent, the thermometer was immediately withdrawn, lest the increasing expansion of the quicksilver should

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burst the glass. The ground was felt tremulous under the feet; a stone thrown violently upon it returned a hollow sound; and the heat was so intense for a considerable distance around, that the foot could not be kept for a quarter of a minute in the same position without being scorched. But the great crater on the eastern side, now full of water, is by far the largest here, or perhaps elsewhere, and is of an astonishing size, considerably exceeding in diameter those of *Etna* or *Vesuvius*. The quantity of matter to be thrown up, which required so wide an orifice for its passage, and the force with which such matter was impelled, in order to overcome the resistance of the superincumbent earth and sea, must have been indeed prodigious.

"This vast crater, according to the usual method of computing the antiquity of volcanoes, must have been formed at a very remote period. The lava all around its sides is much decomposed, and has mouldered into dust, which lies on the surface in many parts to a considerable depth. The decomposition has supplied a rich soil for the long grass growing on the sides of the crater, and has even spread over most parts of the island. The fibrous roots of the grass, extending in all directions through the decomposed lava and volcanic ashes, and mixed in a decaying state with the vegetable mould, produced from the annual putrefaction of the leaves and stalks, have formed a layer of soil several feet deep all over the island. But as it has nothing except its own weight to compress it together, it is of a light spongy texture, with very little cohesion, and in many places furrowed and intersected by the summer rains, and the torrents occasioned by the melting of the snow which lies upon it in the winter, from three to four feet thick, in all those places where the subterraneous heat is not great enough to prevent its accumulation. In some parts these furrows and cavities are deeper than the level of the common channel; hence they serve the purpose of small natural reservoirs. The water flows into them from all the neighbouring ground; and as their sides are shaded, and almost covered over by the leaves of the long grass, growing from their edges in opposite directions, the rays of the sun are excluded, and very little is lost by evaporation. These reservoirs, however, are very small, and but few in number; the largest could not contain more than three or four hog-heads of water; and there is none else to be found, except in the springs on the sides of the large crater.

"The soil everywhere being light and spongy, and full of holes, formed in it by sea-birds for nests, is very troublesome to walk upon; the foot breaks through the surface, and sinks deep at every step; a circumstance which renders the journey across the island uncommonly fatiguing, although it be scarcely three miles from the edge of the great crater to the opposite west side. There is one place near the centre of the island, extending about 200 yards in length, and somewhat less in breadth, where particular caution is necessary in walking over it. From this spot a hot fresh spring is supposed to derive its source, finding its way through the interstices of the lava to the great crater, and bursting out a little above the water covering its bottom. The heat in this upper spot is too great to admit of vegetation. The surface is covered with a kind of mud or paste formed from the ashes, moistened by steam constantly rising from below. When the mud is removed,

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the vapour issues forth with violence, and in some parts copiously. This mud is so hot, that a gentleman who inadvertently stepped into it had his foot severely scalded by it. The same causes which have prevented vegetation on this spot, have had the same effect on the four cones recently thrown up. Their surfaces are covered with ashes only; nor is there the least appearance even of moss on the surrounding lava, for the production of which there does not appear to have elapsed a sufficient length of time since the cones were formed: but this is not the case with the lava of the great primary crater; for in those parts of it where the edges are more perpendicular, and where consequently the mouldering decomposed earth, having no basis to support it, slides down the sides of the rock, pretty long moss was generally found growing upon it. All the springs or reservoirs of hot water, except one only, were brackish. One spring derives its source from the high ground and ridges of the crater. The water in it, instead of boiling upwards through the stones and mud, as in the other springs, flows downward with a considerable velocity, in a small collected stream. Its temperature has been found not to exceed 112 degrees. The hand could be easily kept in it for a considerable time. It is a pretty strong chalybeate. The sides of the rock whence it issues, and of the cavity into which it falls, are incrustated with ochre deposited from it.

“ When the great crater is viewed from the high ground, it appears to have been originally a perfect circle, but to have been encroached upon by the sea on the eastern side, where the flood tide strikes violently. The rocks of lava which formed the edge of the crater on that side have fallen down. The depth of the water in the crater is about 170 feet, rendering the whole height of the crater, from the bottom to its upper ridge, nearly if not quite 900 feet. The lofty rocks forming this ridge are the highest parts of the island, which seems to have been originally produced by the melted lava flowing down on all sides from hence. Thus there is a gradual slope from the edges of the crater to the sea; and the lava, though very irregular, and lying in mixed ruin and confusion immediately around the crater, assumes a more uniform appearance at some distance, layer resting regularly upon layer, with a gradual declivity the whole way down to the sea. This disposition of the layers is particularly observable in the west side, where they happen to terminate in an abrupt precipice. The eruptions that took place at different periods appear here distinctly marked by the different layers that are found with regular divisions between them; the glassy lava being undermost, the compact next, the cellular lava next above, over it the volcanic ashes and lighter substances, and a layer of vegetable mould covering the whole.”

The island appears indeed in such a state of volcanic inflammation, that from the ships decks at night were observed, upon the heights of the island, several fires issuing out of the crevices of the earth, more considerable, but in other respects resembling somewhat the nightly flames at Pietra Mala, in the mountains between Florence and Bologna, or those near Bradley in Lancashire, occasioned by some of the coal-pits having taken fire. In the day nothing more than smoke could be perceived.

The length of the island from north to south is up-

wards of four miles, its breadth from east to west about two miles and a half, and its circumference eleven miles, comprehending a surface of about eight square miles, or 5120 acres, almost the whole of which is covered with a fertile soil. The island is inaccessible except on the east side, where the great crater forms a harbour, the entrance to which is deepening annually, and might by the aid of art be made fit for the passage of large ships. The tides run in and out at the rate of three miles an hour, and rise perpendicularly eight or nine feet on the full and change of the moon; a northerly wind making the highest tide. The water is eight or ten fathoms deep close to the edge of the crater; and in the basin formed by the crater itself, the variation of the compass was found to be nineteen degrees and fifty minutes westward of the north pole.

On the island, which has no native inhabitants, were found three Frenchmen and two natives of England, who at the end of the American war had emigrated to Boston. The whole five had come last from the Isle of France in the Indian Ocean, and had been left on the island of Amsterdam, about five months before the arrival of the *Lion*, for the purpose of procuring a cargo of 25,000 seal-skins for the Canton market, which, as they had already procured 8000, they hoped to complete in about ten months more. The vessel which brought them from the Isle of France was gone to Nootka Sound, with a view of bringing a quantity of sea-otter skins to China; and afterwards of calling for the cargo of seal-skins at this place, to be carried to China likewise; proceeding thus alternately to Nootka and Amsterdam island as long as the owners should find their account in it.

The seals, whose skins are thus an article of commerce, are found here in greater numbers in the summer than in the winter, when they generally keep in deep water, and under the weeds, which shelter them from the inclemency of the weather. In the summer months they come ashore, sometimes in droves of 800 or 1000 at a time, out of which about 100 are destroyed, that number being as many as five men can skin and peg down to dry in the course of a day. Little of the oil which these animals might furnish is collected, for want of casks to put it in; part of the best is boiled, and serves those people instead of butter. The seal of Amsterdam is the *phoca ursina* of Linnæus. The female weighs usually from 70 to 120 pounds, and is from three to five feet in length, but the male is considerably larger. In general they are not shy: sometimes they plunge into the water instantly upon any one's approach, but at other times remain steadily on the rocks, bark, and rear themselves up in a menacing posture; but the blow of a stick upon the nose seemed sufficient to dispatch them. As the skins alone were the objects wanted, the carcases were left on the ground to putrefy at leisure, strewed in such numbers as to render it difficult to avoid trading on them in walking along. The people thus employed were remarkable for the squalor and filth of their persons, clothes, and dwelling; yet none of them seemed desirous of leaving the place before the business they came upon should be completed. One of them, an Englishman, who had been a considerable time upon the island on a former adventure, gave but an unfavourable account of the weather during the winter months, which are always boisterous,

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boisterous, with hail and snow; but in summer he acknowledged it to be very fine.

The sea supplies this island with great varieties of excellent fish, particularly a kind of cod, which was equally relished whether fresh or salted. Cray fish were in such abundance on the bar across the entrance into the crater, that at low water they might be taken with the hand; and at the anchorage of the ships, when baskets, in which were proper baits, were let down into the sea, they were in a few minutes drawn up filled with cray fish. This circumstance is the more extraordinary, that in the same place were found abundance of sharks and dog fish of uncommon size, which are known to be so voracious and such enemies to all other fish. The basin of the crater abounds with tench, bream, and perch; and the person who with a hook and line has caught any of these fish in the cold water of the basin, may with a slight motion of his hand let them drop into the adjoining hot spring already mentioned, in which they will be boiled and rendered fit for eating in the space of fifteen minutes. This was often practised by the gentlemen of the embassy, and furnished them at once with a singular amusement and a highly relished repast.

Of all the birds which frequent this island, so extraordinary in its origin, formation, and appearance, not one is common to the same degree of latitude in the northern hemisphere. Of the larger kind were several species of the *albatross*; on examining one of which, distinguished by the name of *exulans*, it was found, that instead of having only the rudiments of a tongue, as naturalists generally suppose, it had one equalling half the length of the bill. Another large bird is likewise common here, called the great *black petrel*, or *procellaria equinoctialis* of Linnæus. It is the determined enemy of the albatross, as well as of the *blue petrel* of Amsterdam, or *procellaria forsteri*. This blue petrel, which is about the size of a pigeon, constitutes the principal food of the seal catchers on the island. During the day-time they hide themselves in the ground, in order to escape, if possible, their destroyer the black petrel. At night they come abroad, and thence are termed *night birds* by the people at Amsterdam; but being fond of flocking to any light, they fall into another snare laid for them by the seal-catchers, who kindle torches to attract them, and then kill them in multitudes. The prettiest of the feathered tribe, inhabiting or visiting Amsterdam, is the silver bird, or *sterna hirundo*, about the size of a large swallow or swift, with a forked or swallow tail. The bill and legs are of a bright crimson colour, the belly white, and the back and wings of a bluish ash colour. This bird subsists chiefly on small fish, which it picks up as they are swimming over the surface of the water.

This singular island lies in 38° 42' S. Lat. and in 76° 54' E. Long. from Greenwich. ST PAUL'S, or the island lying in sight and to the northward, differed in appearance materially from Amsterdam. It presented no very high land, or any rising in a conic form; and seemed to be overspread with shrubs or trees of a middling size. It was said to abound with fresh water, but to have no good anchorage near it, nor any place of easy landing.—*Sir George Staunton's Account of an Embassy to the Emperor of China.*

ANACLASTIC CURVES, a name given by M. de Mairan to certain apparent curves formed at the bot-

tom of a vessel full of water, to an eye placed in the air; or the vault of the heavens, seen by refraction through the atmosphere.

ANAPHORA, in astrology, the second house, or that part of the heavens which is 30 degrees from the horoscope. The term *anaphora* is also sometimes applied promiscuously to some of the succeeding houses, as the 5th, the 8th, and the 11th. In this sense *anaphora* is the same as *epanaphora*, and stands opposed to *cataphora*.

ANASTROUS SIGNS, in astronomy, a name given to the *duodeceteriora*, or the twelve portions of the ecliptic, which the signs possessed anciently, but have since deserted by the precession of the equinox.

ANCHOR OF A SHIP, is an instrument which, as it is commonly made, has been sufficiently described in the Encyclopædia. An improvement, however, has been proposed on its construction by Mr James Stuard of the parish of St Anne, Middlesex, who obtained a patent for his invention, dated Feb. 1796.

The whole of this invention consists in making the anchor with one fluke or arm instead of two, and contriving to load that fluke or arm in such a manner as to make it always fall the right way. With this view Mr Stuard would have the shank of the anchor made very short, that it may *cant* the more when suspended by the cable; and he would have the arm and it made of bars in one length, that there may be no shoot or joining in the whole instrument. The bend of the shank and arm he would have rounded, and not angular as in the common anchor; and on this bend he would have a small shackle, or two plates with a small bolt between them, for the buoy-rope to be made fast to. Instead of wood, he proposes for the stock of the anchor a bar of wrought iron, loaded or covered at the ends with knobs of cast iron; and he would have the palm of the fluke or arm either to be composed entirely of cast iron, or to be a cast iron shell filled with lead. This weight of the palm, the shortness of the shank, and the structure of the stock, will no doubt make the anchor fall the right way; which, having no upper fluke, will never be tripped by the cable taking hold of it on the ship's swinging, nor will it prove so dangerous as the common anchor to such vessels as may happen to ground by it.

ANDERSON (Alexander), an eminent mathematician, was born at Aberdeen towards the end of the 16th century. Where he was educated, or under what masters, we have not learned; probably he studied the belles lettres and philosophy in the university of his native city, and, as was the practice in that age of all who could afford it, went afterwards abroad for the cultivation of other branches of science. But wherever he may have studied, his progress in science must have been rapid; for, early in the 17th century, we find him professor of mathematics in the university of Paris, where he published several ingenious works; and among others, 1. *Supplementum Apollonii Redivivi; sive analysis problematis hæcenus desiderati ad Apollonii Pergæi doctrinam* (απει νευστων), a Marino Ghetaldo Patrio Ragusino hujusque, non ita pridem restitutam. In qua exhibitur mechanicæ æqualitatum tertii gradus sive solidarum, in quibus magnitudo omnino data, æquavit homogeneæ sub altero tantum coefficiente ignoto. Huic subnexa est variorum problematum præctice, Paris, 1612, in 4to.—2. *Αριθμογία: Προ Ζητητικο Απολλωνιανι problematis a se jam pridem edito in*

Anaphora
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Anderfon, *supplemento Apollonii Redivivi. Ad clarissimum et ornatissimum virum Marinum Ghetaldum Patritium Ragusinum. In qua ad ea quæ obiter mihi perstrinxit Ghetaldus respondetur, et analytices clarius detegitur.* Paris, 1615, in 4to.—3. *Francisci Vietæ Fontenacensis de Æquationum Recognitione et Emendatione Tractatus duo*, with a dedication, preface, and appendix, by himself. Paris, 1615, in 4to.—4. Vietæ's *Angulares Sectiones*; to which he added demonstrations of his own. Our professor was cousin-german to Mr David Anderfon of Finshaugh, a gentleman who also possessed a singular turn for mathematical knowledge. This mathematical genius was hereditary in the family of the Anderfons; and from them it seems to have been transmitted to their descendants of the name of Gregory, who have for so many generations been eminent in Scotland as professors either of mathematics, or, more lately, of the theory and practice of physic. The daughter of the David Anderfon just mentioned, was the mother of the celebrated James Gregory, inventor of the reflecting telescope; and observing in her son, while yet a child, a strong propensity to mathematical studies, she instructed him in the elements of that science herself. From the same lady descended the late Dr Reid of Glasgow, who was not less eminent for his knowledge of mathematics than for his writings as a metaphysician.

The precise dates of Alexander Anderfon's birth and death, we have not learned either from Dempster, Mackenzie, or Dr Hutton, who seems to have used every endeavour to procure information; nor are such of his relations as we have had an opportunity of consulting, so well acquainted with his private history as we expected to find them.

ANHINGA, in ornithology, a species of the pelicanus, consists of four known varieties; two peculiar to America, one to Senegal, and the fourth to the region about the Cape of Good Hope. This last is thus described by Le Vaillant in his *New Travels into the Interior Parts of Africa*.

"The denomination of *Slange-Hals-Voogel*, given to it by the Hottentots, characterises the anHINGA in a very simple and accurate manner. Buffon, who was struck with the conformation peculiar to birds of this kind, has delineated them by a similar expression. 'The anHINGA (says he) exhibits a reptile grafted on the body of a bird.' Indeed there is no person who, upon seeing the head and neck only of an anHINGA, while the rest of the body is hid among the foliage of the tree on which it is perched, would not take it for one of those serpents accustomed to climb and reside in trees; and the mistake is so much the easier, as all its tortuous motions singularly favour the illusion. In whatever situation the anHINGA may be seen, whether perched on a tree, swimming in the water, or flying in the air, the most apparent and remarkable part of its body is sure to be its long and slender neck, which is continually agitated by an oscillatory motion, unless in its flight, when it becomes immovable and extended, and forms with its tail a perfectly straight and horizontal line

"The true place which nature seems to have assigned to the anHINGAS, in the numerous class of the palmipedes, is exactly between the cormorant and the grebe. They partake indeed equally of both these genera of birds, having the straight slender bill and the long neck

of the latter; while they approach the former by the conformity of their feet, the four toes of which are joined by a single membrane. They partake also of the cormorant by their flight; having like it the wings larger and fitter for the purpose than those of the grebe, which are short and weak. The tail of the anHINGA is extremely long; a characteristic very singular and remarkable in a water fowl, and which ought, it would seem, to render them totally distinct from diving birds, which in general have little or no tail. By this trait they approach still nearer to the cormorants; for tho' the tails of the latter are shorter, the tails of both have a great resemblance to each other, since their quills are equally strong, elastic, and proper to form a rudder when these fowls swim through the water in pursuit of fish, which constitute their principal nourishment. When the anHINGA seizes a fish, he swallows it entire if it be small enough, and if too large he carries it off to a rock or the stump of a tree, and fixing it under one of his feet, tears it to pieces with his bill.

"Though water is the favourite element of this bird, it builds its nest and rears its young on rocks and trees; but it takes great care to place them in such a manner, that it can precipitate them into a river as soon as they are able to swim, or the safety of the little family may require it."

The male anHINGA differs from the female, which is smaller, in having the whole under part of the body, from the breast to the root of the tail, of a beautiful black, while the latter has the same parts of a yellow isabella colour. It has also, on each side of its neck, a white stripe, which extends from the eye to the middle of its length, and intersects a reddish ground. A very singular characteristic, common to all the anHINGAS, is that of having the feathers of the tail deeply striated, and as it were ribbed. It is a very sagacious bird, especially when surpris'd swimming; for its head is the only part which it exposes above the water; and if the sportsman once mis's that part, the anHINGA plunges out of sight entirely, and never more shows itself but at very great distances, and then no longer at a time than is absolutely necessary for breathing.

ANTECEDENTAL CALCULUS. See **CALCULUS** in this Supplement.

ANIES, in architecture, small pilastres placed at the corners of buildings.

ANTICS, in architecture, figures of men and animals placed as ornaments to buildings.

ANTICUM, in architecture, a porch; also that part of a temple which lies between the body of the temple and the portico, and is therefore called the outer temple.

ANTIMETER, or **REFLECTING SECTOR**, an instrument invented by Mr William Garrard, for the purpose of measuring angles, particularly small ones, with a greater degree of accuracy than can be done by Hadley's quadrant or by the sextant.

The frame of this instrument is similar to that of Hadley's quadrant, having two radii, a limb, and braces; but with this difference, that the further radius is produced upwards of four inches beyond the centre of motion of the index; and the great speculum, or what is called the index-glass in Hadley's quadrant, being placed there, is called the *upper centre*. In this instrument there is no provision for the back observation.

The

Anderfon,
AnHINGA.

AnHINGA
Antimeter.

Plate III.

Antimeter. The horizon-glass is like that in Hadley's quadrant; there are two sight vanes, to suit two different situations of the large speculum or object glass: these vanes are adapted to receive a small telescope. On the centre of the index, where the index-glass of Hadley's quadrant is fixed, is a brass or bell-metal semicircle, two inches in diameter, and one-eighth of an inch thick: this semicircle is screwed fast to the index, in such a manner that the axis of the index is a tangent to it. On the upper centre are two circular brass plates, which revolve concentrically, either together or separately. The under plate has a lever, or part perpendicular to the plane of the instrument, projecting downwards, a little beyond the lower centre: this lever is acted upon by the semicircular plate at the lower centre, to which it is always kept close by a spring on the other side. In the upper of the above mentioned circular plates are two circular perforations or slits, through one of which a screw takes into the head of the instrument, and through the other a screw takes into the lower moveable plate. The large speculum is fastened to the upper plate; and by the above mentioned screws the position of this glass may be altered. A circular plate is fixed to the lower centre by three pillars: in its centre is a nut to admit a screw, by which the plate carrying the large speculum may be fastened here occasionally.

The scale on the limb is divided into 45 equal parts or degrees, and not into half degrees, as is the case in Hadley's quadrant, by reason of the double reflection. These divisions are numbered in a retrograde order; zero being at the extremity of the further radius. Although the limb contains 45 degrees, yet the greatest angle which can be measured, the large speculum remaining fixed to the circular plate, is $10^{\circ} 18' 21''.8$; the distance between the two centres being four inches, and the radius of the semicircle one inch. Agreeable to these dimensions, the inventor has given a table exhibiting the value of each primary division on the limb; he hath also given a more ample table, adapted to a distance between the centres of three times the radius of the semicircle, which he says hath been found the most convenient in practice. If an angle greater than $10^{\circ} 18'$ is wanted, it may be measured by the method of *anticipation*, as the inventor calls it, which is as follows: Let the screw which fastens the two circular plates on the upper centre be made fast, and loosen the screw which fastens the upper circular plate to the instrument: Now adjust the glasses by the usual method; bring forward the index to any given division on the limb, and make it fast; also fasten the screw which was before loose, and loosen the other screw; then bring the index to zero, and proceed as before.

The inventor gives the following directions for adjusting and using the instrument.

The first thing to be attended to is, to set the horizon-glass perpendicular to the plane of the instrument, which is performed as follows: Hold the instrument with its plane perpendicular to the horizon, and look over backwards into the glass and beyond it. If the limb of the instrument appears in a right line with its reflection, the glass is upright; but if it does not appear so, loosen or tighten the little screw on the foot of the glass until it be adjusted: Then with the instrument, as in taking an altitude, look through the sight vane or telescope at some distant object, with the index fixed

in any intended situation: the two screws at the upper centre being loose, turn the glass about till the same object appears nearly in the same part of the horizon-glass: Next hold it in a horizontal position, and adjust the object-glass or large speculum with the screws which are behind and before, on the foot of it, till the object and its reflection are seen in the same horizontal line. Lastly, with the instrument upright, turn the tangent-screw belonging to the horizon-glass at the back of the instrument, until there be a perfect coincidence of the object and its reflection that way, and the adjustments are complete.

ANTIPARALLELS, in geometry, are those lines which make equal angles with two other lines, but contrariwise; that is, calling the former pair the first and second lines, and the latter pair the third and fourth lines, if the angle made by the first and third lines be equal to the angle made by the second and fourth, and contrariwise the angle made by the first and fourth equal to the angle made by the second and third; then each pair of lines are antiparallels with respect to each other, viz. the first and second, and the third and fourth. So, if AB and AC be any two lines, and FC and FE be two others, cutting them so,

that the angle B is equal to the angle E,
and the angle C is equal to the angle D;
then BC and DE are antiparallels with respect to AB and AC; also these latter are antiparallels with regard to the two former. It is a property of these lines, that each pair cuts the other into proportional segments, taking them alternately,

viz. $AB : AC :: AE : AD :: DB : EC,$
and $FE : FC :: FB : FD :: DE : BC.$

APERTURE, in optics, has been defined in the Encyclopædia, but no rule was given there for finding a just aperture. As much depends upon this circumstance, our optical readers will be pleased with the following practical rule given by Dr Hutton in his Mathematical Dictionary. "Apply several circles of dark paper, of various sizes, upon the face of the glass, from the breadth of a straw to such as leave only a small hole in the glass; and with each of these, separately, view some distant object, as the moon, stars, &c. then that aperture is to be chosen through which they appear the most distinctly.

"Huyghens first found the use of apertures to conduce much to the perfection of telescopes; and he found by experience (*Diopt.* prop. 56.), that the best aperture for an object-glass, for example of 30 feet, is to be determined by this proportion, as 30 to 3, so is the square root of 30 times the distance of the focus of any lens to its proper aperture: and that the focal distances of the eye-glasses are proportioned to the apertures. And M. Auzout says he found, by experience, that the apertures of telescopes ought to be nearly in the sub-duplicate ratio of their lengths. It has also been found by experience, that object-glasses will admit of greater apertures, if the tubes be blacked within side, and their passage furnished with wooden rings.

"It is to be noted, that the greater or less aperture of an object-glass, does not increase or diminish the visible area of the object; all that is effected by this is the admittance of more or fewer rays, and consequently the more or less bright the appearance of the object. But the largeness of the aperture or focal distance causes

Antiparallels,
Aperture.

Plate II.
fig. 5.

Apocatastasis the irregularity of its refractions. Hence, in viewing Venus through a telescope, a much less aperture is to be used than for the moon, or Jupiter, or Saturn, because her light is so bright and glaring. And this circumstance somewhat invalidates and disturbs Azont's proportion, as is shown by Dr Hook, Phil. Trans. No 4."

APOCATASTASIS, or, as it should be written, **ΑΠΟΚΑΤΑΣΤΑΣΙΣ**, is a Greek word employed in the language of astronomers, to denote the period of a planet, or the time it takes to return to that point of the zodiac whence it set out.

APOTOME, is a term employed by Euclid to denote the difference between two lines or quantities which are only commensurable in power. Such is the difference between 1 and $\sqrt{2}$, or the difference between the side of a square and its diagonal. The doctrine of apotomes in lines, as delivered by this ancient mathematician in the tenth book of his Elements, is a very curious subject, and has always been admired by such as understood it. The first algebraical writers in Europe, such as Lucas de Burgo, Cardan, Tartalea, Stifelius, &c. employed a considerable portion of their works on an algebraical exposition of that which led them to the doctrine of surd quantities.

APPARENT CONJUNCTION of the planets, is when a right line, supposed to be drawn through their centres, passes through the eye of the spectator, and not through the centre of the earth. And, in general, the apparent conjunction of any objects, is when they appear or are placed in the same right line with the eye.

APPARENT Diameter of a planet or other heavenly body, is not the real length of the diameter of that body, but the angle which it subtends at the eye, or under which it appears.

APPARENT Distance, is that which we judge an object to be from us when seen afar off; and which is almost always very different from the true distance.

APPARENT Figure, is the figure or shape under which an object appears when viewed at a distance; and is often very different from the true figure. Thus a straight line, viewed at a distance, may appear but as a point, as a surface, as a line; and a solid, as a surface.

APPARENT Motion, is either that motion which we perceive in a distant body that moves, the eye at the same time being either in motion or at rest; or that motion which an object at rest seems to have, while the eye itself only is in motion.

APPARENT Place of a Planet, &c. in astronomy, is that point in the surface of the sphere of the world where the centre of the luminary appears from the surface of the earth.

APPARITION, in astronomy, denotes a star's or other luminary's becoming visible, which before was hid. So, the heliacal rising, is rather an apparition than a proper rising.

Arch defined.

ARCH, in building, is an artful disposition and adjustment of several stones or bricks, generally in a bow-like form, by which their weight produces a mutual pressure and abutment; so that they not only support each other, and perform the office of an entire lintel, but may be extended to any width, and made to carry the most enormous weights.

In those mild climates which seem to have been the first inhabited parts of this globe, mankind stood more

in need of shade from the sun than of shelter from the inclemency of the weather. A very small addition to the shade of the woods served them for a dwelling. Sticks laid across from tree to tree, and covered with brushwood and leaves, formed the first houses in those delightful regions. As population and the arts improved, these huts were gradually refined into commodious dwellings. The materials were the same, but more artfully put together. At last agriculture led the inhabitants out of the woods into the open country. The connection between the inhabitant and the soil became now more constant and more interesting. The wish to preserve this connection was natural, and fixed establishments followed of course. Durable buildings were more desirable than those temporary and perishable cottages—stone was substituted for timber.

But as these improved habitations were gradual refinements on the primitive hut, traces of its construction remained, even when the choice of more durable materials made it in some measure inconvenient. Thus it happened, that while a plain building, intended for accommodation only, consisted of walls, pierced with the necessary doors and windows, an ornamented building had, superadded to these essentials, columns, with the whole apparatus of entablature, borrowed from the wooden building, of which they had been essential parts, gradually rendered more suitable to the purposes of accommodation and elegance.

This view of ornamental architecture will go far to account for some of the more general differences of national style which may be observed in different parts of the world. The Greeks borrowed many of their arts from their Asiatic neighbours, who had cultivated them long before. It is highly probable that architecture travelled from Persia into Greece. In the ruins of Shushan, Persepolis, or Tchilmiran, are to be seen the first models of every thing that distinguishes the Grecian architectures. There is no doubt, we suppose, among the learned, as to the great priority of these monuments to any thing that remains in Greece; especially if we take into account the tombs on the mountains, which have every appearance of greater antiquity than the remains of Persepolis. In those tombs we see the whole *ordonnance* of column and entablature, just as they began to deviate from their first and necessary forms in the wooden buildings. We have the architrave, frieze, and cornice; the far-projecting mutules of the Tuscan and Doric orders; the modillions no less distinct; the rudiments of the Ionic capital; the Corinthian capital in perfection, pointing out the very origin of this ornament, viz. a number of long graceful leaves tied round the head of the column with a fillet (a custom which we know to have been common in their temples and banqueting rooms). Where the distance between the columns is great, so that each had to support a weight too great for one tree, we see the columns clustered or fluted, &c. In short, we see every thing of the Grecian architecture but the sloped roof or pediment; a thing not wanted in a country where it hardly ever rains.

The ancient Egyptian architecture seems to be a refinement on the hut built of clay or unburnt bricks mixed with straw; every thing is massive, clumsy, and timid; small intercolumnations, and hardly any projections.

The Arabian architecture seems a refinement on the Arabian tent. A mosque is like a little camp, consisting of a and number

Arch.

History of architecture connected with arches.

Origin of Greek architecture.

Egyptian.

5

Arch. number of little bell tents, stuck close together round a great one. A caravaneray is a court surrounded by a row of such tents, each having its own dome. The Greek church of St Sophia at Constantinople has imitated this in some degree; and the copies from it, which have been multiplied in Russia as the sacred form for a Christian church, have adhered to the original model of clustered tents in the strictest manner. We are sometimes disposed to think that the painted glass (a fashion brought from the East) was in imitation of the painted hangings of the Arabs.

6 Chinese architecture. The Chinese architecture is an evident imitation of a wooden building. Sir Geo. Staunton says, that the singular form of their roofs is a *professed* imitation of the cover of a square tent.

In the stone-buildings of the Greeks, the roofs were imitations of the wooden ones; hence the lintels, flying corniches, ceilings in compartments, &c.

The pediment of the Greeks seems to have suggested the greatest improvement in the art of building. In erecting their small houses, they could hardly fail to observe occasionally, that when two rafters were laid together, from the opposite walls, they would, by leaning on each other, give mutual support, as in fig. 1. Nor is it unlikely that such a situation of stones as is represented in fig. 2. would not unfrequently occur by accident to masons. This could hardly fail of exciting a little attention and reflection. It was a pretty obvious reflection, that the stones A and C, by overhanging, leaned against the intermediate stone B, and gave it some support, and that B cannot get down without thrusting aside A and C, or the piers which support them. This was an approach to the theory of an arch; and if this be combined with the observation of fig. 1. we get the disposition represented in fig. 3. having a perpendicular joint in the middle, and the *principle of the arch* is completed. Observe that this is quite different from the principle of the arrangement in fig. 2. In that figure the stones act as wedges, and one cannot get down without thrusting the rest aside; the same principle obtains in fig. 4. consisting of five arch stones; but in fig. 3. the stones B and C support each other by their mutual pressure (independent of their own weight), arising from the tendency of each lateral pair to fall outwards from the pier. This is the principle of the arch, and would support the key-stone of fig. 4. although each of its joints were perpendicular, by reason of the great friction arising from the horizontal thrust exerted by the adjoining stones.

This was a most important discovery in the art of building; for now a building of any width may be roofed with stone.

8 Grecian. We are disposed to give the Greeks the merit of this discovery; for we observe arches in the most ancient buildings of Greece, such as the temple of the sun at Athens, and of Apollo at Didymos; not indeed as roofs to any apartment, nor as parts of the ornamental design, but concealed in the walls, covering drains or other necessary openings; and we have not found any *real* arches in any monuments of ancient Persia or Egypt. Sir John Chardin speaks of numerous and extensive subterranean passages at Tchilminar, built of the most exquisite masonry, the joints so exact, and the stones so beautifully dressed, that they look like one continued piece of polished marble: but he nowhere

fays that they are arched; a circumstance which we think he would not have omitted—no arched door or window is to be seen. Indeed one of the tombs is said to be arch-roofed, but it is all of one solid rock. No trace of an arch is to be seen in the ruins of ancient Egypt; even a wide room is covered with a single block of stone. In the pyramids, indeed, there are two galleries, whose roofs consist of many pieces; but their construction puts it beyond doubt that the builder did not know what an arch was: for it is covered in the manner represented in fig. 5. where every projecting piece is more than balanced behind, so that the whole awkward mass could have stood on two pillars. The Greeks therefore seem entitled to the honour of the invention. The arched dome, however, seems to have arisen in Etruria, and originated in all probability from the employment of the augurs, whose business it was to observe the flight of birds. Their stations for this purpose were *templa*, so called a *templando*, “on the summits of hills.” To shelter such a person from the weather, and at the same time allow him a full prospect of the country around him, no building was so proper as a dome set on columns; which accordingly is the figure of a temple in the most ancient monuments of that country. We do not recollect a building of this kind in Greece except that called the *Lantern of Demosthenes*, which is of very late date, whereas they abounded in Italy. In the later monuments and coins of Italy or of Rome, we commonly find the Etruscan dome and the Grecian temple combined; and the famous pantheon was of this form, even in its most ancient state.

It does not appear that the arch was considered as a part of the *ornamental* architecture of the Greeks during the time of their independency. It is even doubtful whether it was employed in roofing their temples. In none of the *ancient* buildings where the roof is gone, can there be seen any rubbish of the vault, or mark of the spring of the arch. It is not unfrequent, however, after the Roman conquests, and may be seen in Athens, Delos, Palmyra, Balbek, and other places. It is very frequent in the magnificent buildings of Rome; such as the Coliseum, the baths of Dioclesian, and the triumphal arches, where its form is evidently made the object of attention. But its chief employment was in bridges and aqueducts; and it is in those works that its immense utility is the most conspicuous: For by this happy contrivance a canal or a road may be carried across any stream, where it would be almost impossible to erect piers sufficiently near to each other for carrying lintels. Arches have been executed 130 feet wide, and their execution demonstrates that they may be made four times as wide.

As such stupendous arches are the greatest performances of the masonic art, so they are the most difficult and delicate. When we reflect on the immense quantity of materials thus suspended in the air, and compare this with the small cohesion which the firmest cement can give to a building, we shall be convinced that it is not by the force of the cement that they are kept together: they stand fast only in consequence of the proper balance of all their parts. Therefore, in order to erect them with a well-founded confidence of their durability, this balance should be well understood and judiciously employed. We doubt not but that this was understood in some degree by the engineers of antiquity.

Arch.

Plate I.

7 Origin of the arch.

9 It was used at first only in bridges and aqueducts.

10 Difficulty of constructing it.

Arch.
11
Skill and
mysteries
of the Dio-
nyfiacs.

ty; but they have left us none of their knowledge. They must have had a great deal of mechanical knowledge before they could erect the magnificent and beautiful buildings whose ruins still enchant the world; but they kept it among themselves. We know that the Dionysiacs of Ionia were a great corporation of architects and engineers, who undertook, and even monopolized, the building of temples, stadiums, and theatres, precisely as the fraternity of masons in the middle ages monopolized the building of cathedrals and conventual churches. Indeed the Dionysiacs resembled the mystical fraternity now called free masons in many important particulars. They allowed no strangers to interfere in their employment; they recognized each other by signs and tokens; they professed certain mysterious doctrines, under the tuition and tutelage of Bacchus, to whom they built a magnificent temple at Teos, where they celebrated his mysteries as solemn festivals; and they called all other men profane, because not admitted to these mysteries. But their chief mysteries and most important secrets seem to be their mechanical and mathematical sciences, or all that academical knowledge which forms the regular education of a civil engineer. We know that the temples of the gods and the theatres required an immense apparatus of machinery for the celebration of some of their mysteries; and that the Dionysiacs contracted for those jobs, even at far distant places, where they had not the privilege of building the edifice which was to contain them. This is the most likely way of explaining the very small quantity of mechanical knowledge that is to be met with in the writings of the ancients. Even Vitruvius does not appear to have been of the fraternity, and speaks of the Greek architects in terms of respect next to veneration. The *Collegium Murariorum*, or incorporation of masons at Rome, does not seem to have shared the secrets of the Dionysiacs.

12
The art of
building
arches un-
derstood in
the middle
ages

The art of building arches has been most assiduously cultivated by the associated builders of the middle ages of the Christian church, both Saracens and Christians, and they seem to have indulged in it with fondness: they multiplied and combined arches without end, placing them in every possible situation.

13
Better than
by the
Greeks and
Romans.

Having studied this branch of the art of building with so much attention, they were able to erect the most magnificent buildings with materials which a Greek or Roman architect could have made little or no use of. There is infinitely more scientific skill displayed in a Gothic cathedral than in all the buildings of Greece and Rome. Indeed these last exhibit very little knowledge of the mutual balance of arches, and are full of gross blunders in this respect; nor could they have resisted the shock of time so long, had they not been almost solid masses of stone, with no more cavity than was indispensably necessary.

14
Defects of
the church
of St Sophia
at Constanti-
nople.

Anthemius and Isidorus, whom the Emperor Justinian had selected as the most eminent architects of Greece for building the celebrated church of St Sophia at Constantinople, seem to have known very little of this matter. Anthemius had boasted to Justinian, that he would outdo the magnificence of the Roman pantheon, for he would hang a greater dome than it aloft in the air. Accordingly he attempted to raise it on the heads of four piers, distant from each other about 115 feet, and about the same height. He had probably

seen the magnificent vaultings of the temple of Mars the Avenger, and the temple of Peace at Rome, the thrusts of which are withstood by two masses of solid wall, which join the side walls of the temple at right angles, and extend sidewise to a great distance. It was evident that the walls of the temple could not yield to the pressure of the vaulting without pushing these immense buttresses along their foundations. He therefore placed four buttresses to aid his piers. They are almost solid masses of stone, extending at least 90 feet from the piers to the north and to the south, forming as it were the side walls of the cross. They effectually secured them from the thrusts of the two great arches of the nave which support the dome; but there was no such provision against the push of the great north and south arches. Anthemius trusted for this to the half dome, which covered the semicircular east end of the church, and occupied the whole eastern arch of the great dome. But when the dome was finished, and had stood a few months, it pushed the two eastern piers with their buttresses from the perpendicular, making them lean to the eastward, and the dome and half dome fell in. Isidorus, who succeeded to the charge on the death of Anthemius, strengthened the piers on the east side, by filling up some hollows, and again raised the dome. But things gave way before it was closed; and while they were building in one part it was falling in in another. The pillars and walls of the eastern semicircular end were much shattered by this time. Isidorus seeing that they could give no resistance to the push which was so evidently directed that way, erected some clumsy buttresses on the east wall of the square which surrounded the whole Greek cross, and was roofed in with it, forming a sort of cloister round the whole. These buttresses, spanning over this cloister, leaned against the piers of the dome, and thus opposed the thrusts of the great north and south arches. The dome was now turned for the third time, and many contrivances were adopted for making it extremely light. It was made offensively flat; and, except the ribs, it was roofed with pumice stone; but, notwithstanding these precautions, the arches settled so as to alarm the architects, and they made all sure by filling up the whole from top to bottom with arcades in three stories. The lowest arcade was very lofty, supported by four noble marble columns, and thus preserved, in some measure, the church in the form of a Greek cross. The story above formed a gallery for the women, and had six columns in front, so that they did not bear fair on those below. The third story was a dead wall filling up the arch, and pierced with three rows of small ill-shaped windows. In this unworkmanlike shape it has stood till now, and is the oldest church in the world; but it is an ugly mishapen mass, more resembling an overgrown potter's kiln, surrounded with furnaces pieced and patched, than a magnificent temple. We have been thus particular in our account of it, because this history of the building shows that the ancient architects had acquired no distinct notions of the action of arches. Almost any mason of our time would know, that as the south arch would push the pier to the eastward, while the east arch pushed it to the southward, the buttress which was to withstand these thrusts must not be placed on the south side of the pier, but on the south-east side. or that there must be an eastern as well as a southern buttress. No such blunders are to be seen

Arch.

15
Such as are
never found
in a Gothic
church.

Arch. in a Gothic cathedral. Some of them appear, to a careful spectator, to be very massive and clumsy; but when judiciously examined, they will be found very bold and light, being pierced in every direction by arcades, and the walls are divided into cells like a honeycomb, so that they are very stiff, while they are very light.

About the middle, or rather towards the end, of last century, when the Newtonian mathematics opened the road to true mechanical science, the construction of arches engrossed the attention of the first mathematicians.

¹⁶ Dr Hooke's principle of arches The first hint of a principle that we have met with is Dr Hooke's assertion, that the figure into which a chain or rope, perfectly flexible, will arrange itself when suspended from two hooks, is, when inverted, the proper form for an arch composed of stones of uniform weight. This he affirmed on the same principle which is made use of in the Encyclopædia Britannica in the article Roof, § 25. viz. that the figure which a flexible festoon of heavy bodies assumes, when suspended from two points, is, when inverted, the proper form for an arch of the same bodies, touching each other in the same points; because the forces with which they mutually press on each other in this last case, are equal and opposite to the forces with which they pull at each other in the case of suspension.

This principle is strictly just, and may be extended to every case which can be proposed. We recollect seeing it proposed, in very general terms, in the St James's Chronicle in 1759, when plans were forming for Blackfriar's Bridge in London; and since it is perhaps equal, in practical utility, to the most elaborate investigations of the mathematicians, our readers will not be displeas'd with a more particular account of it in this place.

¹⁷ explained, Let ABC (fig. 6.) be a parcel of magnets of any size and shape, and let us suppose that they adhere with great force by any points of contact. They will compose such a flexible festoon as we have been speaking of, if suspended from the points A and C. If this figure be inverted, preserving the same points of contact, they will remain in equilibrio. It will indeed be that kind of equilibrium which will admit of no disturbance, and which may be called a *tottering equilibrium*. If the form be altered in the smallest degree, by varying the points of contact (which indeed are points in the *figure of equilibration*), the magnets will no more recover their former position than a needle, which we had made to stand on its point, will regain its perpendicular position after it has been disturbed.

But if we suppose planes *de*, *fg*, *hi*, &c. drawn, that the points of mutual contact *a*, *b*, *c*, each bisecting the angle formed by the lines that unite the adjoining contacts (*fg*, for example, bisecting the angle formed by *ab*, *bc*), and if we suppose that the pieces are changed for others of the same weights, but having flat sides, which meet in the planes *de*, *fg*, *hi*, &c. it is evident that we shall have an arch of equilibration, and that the arch will have some stability, or will bear a little change of form without tumbling down: for it is plain that the equilibrium of the original festoon obtained only in the points *a*, *b*, *c*, of contact, where the pressures were perpendicular to the touching surfaces; therefore if the curve *a*, *b*, *c*, still passes through the touching surfaces perpendicularly, the conditions that are required for equilibrium still obtain. The case is quite similar to that of the stability of a body resting on a horizontal

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plane. If the perpendicular through the centre of gravity falls within the base of the body, it will not only stand, but will require some force to push it over. In the original festoon, if a small weight be added in any part, it will change the form of the curve of equilibration a little, by changing the points of mutual contact. This new curve will gradually separate from the former curve as it recedes from A or C. In like manner, when the festoon is set up as an arch, if a small weight be laid on any part of it, it will bring the whole to the ground, because the shifting of the points of contact will be just the contrary to what it should be to suit the new curve of equilibration. But if the same weight be laid on the same part of the arch now constructed with flat joints, it will be sustained, if the new curve of equilibration still passes through the touching surfaces.

These conclusions, which are very obviously deducible from the principle of the festoon, shew us, without any further discussion, that the longer the joints are, the greater will be the stability of the arch, or that it will require a greater force to break it down. Therefore it is of the greatest importance to have the arch stones as long as economy will permit; and this was the great use of the ribs and other apparent ornaments in the Gothic architecture. The great projections of those ribs augmented their stiffness, and enabled them to support the unadorned copartments of the roof, composed of very small stones, seldom above six inches thick. Many old bridges are still remaining, which are strengthened in the same way by ribs.

Having thus explained, in a very familiar manner, the stability of an arch, we proceed to give the same popular account of the general application of the principle.

¹⁸ And applied. Suppose it to be required to ascertain the form of an arch which shall have the span AB (fig. 7.), and the height F 8, and which shall have a road-way of the dimensions CDE above it. Let the figure ACDEB be inverted, so as to form a figure *AcdēB*. Let a chain of uniform thickness be suspended from the points A and B, and let it be of such a length that its lower point will hang at, or rather a little below, *f*, corresponding to F. Divide AB into a number of equal parts, in the points 1, 2, 3, &c. and draw vertical lines, cutting the chain in the corresponding points 1, 2, 3, &c. Now take pieces of another chain, and hang them on at the points 1, 2, 3, &c. of the chain *AfB*. This will alter the form of the curve. Cut or trim these pieces of chain, till their lower ends all coincide with the inverted road-way *cde*. The greater lengths that are hung on in the vicinity of A and B will pull down these points of the chain, and cause the middle point *f* (which is less loaded) to rise a little, and will bring it near to its proper height.

It is plain that this process will produce an arch of perfect equilibration; but some farther considerations are necessary for making it exactly suit our purpose. It is an arch of equilibration for a bridge, that is so loaded that the weight of the arch-stones is to the weight of the matter with which the haunches and crown are loaded, as the weight of the chain *AfB* is to the sum of the weights of all the little bits of chain very nearly. But this proportion is not known beforehand; we must therefore proceed in the following manner: Adapt to the curve produced in this way a thick-

Arch.

ness of the arch-stones as great as are thought sufficient to ensure stability; then compute the weight of the arch stones, and the weight of the gravel or rubbish with which the haunches are to be filled up to the road-way. If the proportion of these two weights be the same with the proportion of the weights of chain, we may rest satisfied with the curve now found; but if different, we can easily calculate how much must be added equal to, or taken from, each appended bit of chain, in order to make the two proportions equal. Having altered the appended pieces accordingly, we shall get a new curve, which may perhaps require a very small trimming of the bits of chain to make them fit the road-way. This curve will be infinitely near to the curve wanted.

We have practised this method for an arch of 60 feet span and 21 feet height, the arch-stones of which were only two feet nine inches long. It was to be loaded with gravel and shivers. We made a previous computation, on the supposition that the arch was to be nearly elliptical. The distance between the points 1, 2, 3, &c. were adjusted, so as to determine the proportion of the weights of chain agreeable to the supposition. The curve differed considerably from an ellipse, making a considerable angle with the vertices at the spring of the arch. The real proportion of the weights of chain, when all was trimmed so as to suit the road-way, was considerably different from what was expected. It was adjusted. The adjustment made very little change in the curve. It would not have changed it two inches in any part of the real arch. When the process was completed, we constructed the curve mathematically. It did not differ sensibly from this mechanical construction. This was very agreeable information; for it shewed us that the first curve, formed by about two hours labour, on a supposition considerably different from the truth, would have been sufficiently exact for the purpose, being in no place three inches from the accurate curve, and therefore far within the joints of the intended arch-stones. Therefore this process, which any intelligent mason, though ignorant of mathematical science, may go through with little trouble, will give a very proper form for an arch subject to any conditions.

19
The chief defect of the curve found according to this principle.

The chief defect of the curve found in this way is a want of elegance, because it does not spring at right angles to the horizontal line; but this is the case with all curves of equilibration, as we shall see by and by. It is not material: for, in the very neighbourhood of the piers, we may give it any form we please, because the masonry is solid in that place; nay, we apprehend that a deviation from the curve of equilibration is proper. The construction of that curve supposes that the pressure on every part of the arch is vertical; but gravel, earth, and rubbish, exert somewhat of a hydrostatical pressure laterally in the act of settling, and retain it afterwards. This will require some more curvature at the haunches of an arch to balance it; but what this lateral pressure may be, cannot be deduced with confidence from any experiments that we have seen. We are inclined to think that if, instead of dividing the horizontal line AB in the points 1, 2, 3, &c. we divide the chain itself into equal parts, the curve will approach nearer to the proper form.

After this familiar statement of the general principle, it is now time to consider the theory founded on it

more in detail. This theory aims at such an adjustment of the position of the arch-stones to the load on every part of the arch, that all shall remain in equilibrium, although the joints be perfectly polished, and without any cement. The whole may be reduced to two problems. The first is to determine the vertical pressure or load on every point of a line of a given form, which will put that line in equilibrium. The second is to determine the form of a curve which shall be in equilibrium when loaded in its different points, according to any given law.

Arch.
Theory
founded on
this principle.

The whole theory is deducible from § 27. of the article Roof. The fundamental proposition in that section states the proportions between the various pressures or thrusts which are exerted at the angles of an assemblage of beams or other pieces of solid heavy matter, freely moveable about those angles, as so many joints, but retaining their position by the equilibrium of those pressures. It is there demonstrated, "that the thrust at any angle, if estimated in a horizontal direction, is the same throughout, and may be represented by any horizontal line BT, fig. 8. (Roofs, fig. 10 Pl. CCCCXL); and that if a vertical line QTS be drawn through T, the thrust exerted at any angle D by the piece CD, in its own direction, will then be represented by BR, drawn parallel to CD; and in like manner, that the thrust in the direction ED is represented by BS, &c.; and, lastly, that the vertical thrusts or loads, at each angle B, C, D, by which all these others pressures are excited, are represented by the portions QC, CR, RS, of the vertical intercepted by those lines; that is, all these pressures are to the uniform horizontal thrust as the lines which represent them are to BT. The horizontal thrust, therefore, is a very proper unit, with which we may compare all the others. Its magnitude is easily deduced from the same proposition; for QS is the sum of all the vertical pressures of the angles, and therefore represents the weight of the whole assemblage. Therefore as QS is to BT, so is the weight of the whole to the horizontal thrust.

To accommodate this theory to the construction of a curvilinear arch vault, let us first suppose the vault to be polygonal, composed of the cords of the elementary arches. Let AVE (fig. 9.) be a curvilinear arch, of which V is the vertex, and VX the vertical axis, which we shall consider as the axis or abscissa of the curve, while any horizontal line, such as HK, is an ordinate to the curve. About any point C of the curve as a centre describe a circle BLD, cutting the curve in B and D. Draw the equal cords CB, CD. Draw also the horizontal line CF, cutting the circle in F. Describe a circle BCDQ passing through B, C, D. Its centre O will let in a line COQ, which bisects the angle BCD; and Cd, which touches this circle in C, will bisect the angle bCd, formed by the equal cords BC, CD. Draw CLP perpendicular to cb, and DP perpendicular to CD, meeting CL in P. Through L draw the tangent GLM, meeting CD in G, and the vertical line CM in M. Draw the tangent Fa, cutting the cords BC, CD, in b and d, and the tangent to the circle BCDQ in c. Lastly, draw dN parallel to bc.

From what is demonstrated in § 27. of the article Roof, it appears, that if BC, CD be two pieces of an equilibrated heavy polygon, and if CF represent the horizontal thrust in every angle of the polygon, Cd and

C b

Arch. Cb will severally represent the thrusts exerted by the pieces DC, BC, and that bd , or CN, will represent the weight lying on the angle BCD, by which those thrusts are balanced.

As the reader may not have the article Roof at hand, this equilibrium may be recalled to his remembrance in the following manner: Produce dC to o , so that Co may be equal to Cd . Draw bn to the vertical parallel to dB , and join no . It is evident that $bnoc$ is a parallelogram, and that $nc (= bd) = CN$. Now the thrust or support of the piece BC is exerted in the direction Cb , while that of DC is exerted in the direction Co . These two thrusts are equivalent to the thrust in the diagonal Cn ; and it is with this compound thrust that the load or vertical pressure CN is in immediate equilibrium.

Because bCL , NCF , are right angles, and FCL is common to both, the angles bCF and MCL are equal. Therefore the right angled triangles bCF and MCL are similar. And since CF is equal to CL , cb is equal to CM . It is evident that the triangles GCM and dCN are similar. Therefore $CG : Cd = CM : CN$,

$= Cb : CN$. Therefore we have $CN = \frac{Cb \times Cd}{CG}$. But because CDP and CLG are right angles, and therefore equal, and the angle GCP is common to the two triangles GCL , PCD , and CD is equal to CL , we have

CG equal to CP . Therefore $CN = \frac{Cb \times Cd}{CP}$. Also,

since CDP is a right angle, DP meets the diameter in Q , the opposite point of the circumference, and the angle DQC is equal to DCd , or DCb (because bCd is bisected by the tangent), that is, to PCQ (because the right angles bCP , cDO are equal, and cDP is common). Therefore PQ is equal to PC ; and if PO be drawn perpendicular to CQ , it will bisect it, and O is the centre of the circle $BCDQB$.

Now let the points B and D continually approach to C (by diminishing the radius of the small circle), and ultimately coincide with it. It is evident that the circle $BCDQ$ is ultimately the equicurve circle, and that PC ultimately coincides with OC , the radius of curvature. Also $Cb \times Cd$ becomes ultimately Cc^2 . Therefore CN , the vertical load on any point of a curve of equilibration, is $= \frac{Cc^2}{\text{Rad. Curv.}}$

It is farther evident, that CF is to Cc as radius to the secant of the elevation of the tangent above the horizon. Therefore we have the load on any point of the curve always proportional to $\frac{\text{Sec.}^2 \text{ Elev.}}{\text{Rad. Curv.}}$

This load on every elementary arch of the wall is commonly a quantity of solid matter incumbent on that element of the curve, and pressing it vertically; and it may be conceived as made up of a number of heavy lines standing vertically on it. Thus, if the element Ee of the curve were lying horizontally, a little parallelogram $REer$ standing perpendicularly on it, would represent its load. But as this element Ee has a sloping position, it is plain that, in order to have the same quantity of heavy matter pressing it vertically, the height of the parallelogram must be increased till it meets in β , the line $R\beta$ drawn parallel to the tangent EG . It is evident that the angle REr is equal to the

angle AEG . Therefore we have $ER : Ee = \text{Rad.} : \text{Sec. Elev.}$

If therefore the arch is kept in equilibrio by the vertical pressure of a wall, we must have the height of the wall above any point proportional to $\frac{\text{Sec.}^2 \text{ Elev.}}{\text{Rad. of Curv.}}$

COR. I. If OS be drawn perpendicular to the vertical CS , CS will be half the vertical cord of the equicurve circle. The angle OCS is equal to cCF , that is, to the angle of elevation. Therefore $1 : \text{Sec. Elev.} = CS : CO$, and the secant of elevation may be expressed by $\frac{CO}{CS}$, and its cube by $\frac{CO^3}{CS^3}$. Therefore the height

of wall is proportional to $\frac{CO^3}{CS^3 \times CO}$, or to $\frac{CO^2}{CS^3}$, or

$\frac{CO^2}{CS^2 \times CS}$, or to $\frac{\text{Sec.}^2 \text{ of Elev.}}{\text{Vert. Cord of Curv.}}$

COR. II. If we make the arch $VC = z$, the abscissa $VH = x$, the ordinate $HC = y$, the radius of culi $CO = r$, and the $\frac{1}{2}$ vertical cord $CS = s$, the height of wall pres-

sing on any point is proportional to $\frac{z^3}{y^3 r}$; or to $\frac{z^2}{y^2 s}$, or $\frac{x^2 + y^2}{y^2 s}$. Therefore, when the equation of the curve

is given, and the height of wall on any one point of it is also given, we can determine it for any other point: for the equation of the curve will always give us the relation of z , x , and y , and the value of r or s . This may be illustrated by an example or two. For this purpose it will generally be most convenient to assume the height above the vertex V for the unit of computation. The thickness of the arch at the crown is commonly determined by other circumstances. At the vertex the tangent to the arch is horizontal, and therefore the cube of the secant is unity or 1. Call the height of wall, at the crown, H , and let the radius of curvature in that point be R , and its half cord R (it being then coincident with the radius), and the height on any other

point b . We have $\frac{1}{R} : \frac{z^3}{y^3 r} = H : b$, and $b = H \times \frac{z^3}{y^3 r}$

$\times \frac{R}{r}$. The other formula gives $b = H \times \frac{z^2}{y^2} \times \frac{R}{s}$.

Exampl. 1. Suppose the arch to be a segment of a circle, as in fig. 10. where AE is the diameter, and O by example the centre. In this arch the curvature is the same

throughout, or $\frac{R}{r} = 1$. Therefore $b = H \times \frac{z^3}{y^3}$, or $= H \times \text{Cube Sec. Elev.}$

This gives a very simple calculus. To the logarithm of H add thrice the logarithm of the secant of elevation, The sum is the logarithm of b .

It gives also a very simple construction. Draw the vertical CS , cutting the horizontal diameter in S . Draw ST , cutting the radius OC perpendicularly in T . Draw the horizontal line Tz , cutting the vertical in z . Join zo . Make $Cu = Vv$, and draw ux parallel to zo . Cx must be made $= Cx$. The demonstration is evident.

It is very easy to see that if CV is an arch of 60° , and Vv is $\frac{1}{2}$ th of VC , the points v and c will be on a level; for the secant of CV is twice CO , and therefore Cc is 8 times Vv , which is $\frac{1}{7}$ th of VH .

23
Corollaries.

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by exam-
ples.

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And demon-
strated.

Arch. The dotted line $vgcf$ is drawn according to this calculus or construction. It falls considerably below the horizontal line in the neighbourhood of c ; and then, passing very obliquely through c , it rises rapidly to an unmeasurable height, because the vertical line through A is its asymptote. This must evidently be the case with every curve which springs at right angles with a horizontal line.

It is plain that if vV be greater, all the other ordinates of the curve $vgcf$, resting on the circumference AVE , will be greater in the same proportion, and the curve will cut the horizontal line drawn through v in some point nearer to v than c is. Hence it appears that a circular arch cannot be put in equilibrio by building on it up to a horizontal line, whatever be its span, or whatever be the thickness at the crown. We have seen that when this thickness is only $\frac{1}{27}$ th of the radius, an arch of 120 degrees will be too much loaded at the flanks. This thickness is much too small for a bridge, being only $\frac{1}{27}$ th of the span CM , whereas it should have been almost double of this, to bear the inequalities of weight that may occasionally be on it. When the crown is made still thinner, the outline is still more depressed before it rises again. There is therefore a certain span, with a corresponding thickness at the crown, which will deviate least of all from a horizontal line. This is an arch of about 54 degrees, the thickness at the crown being about one-fourth of the span, which is extravagantly great. It appears in general, therefore, that the circle is not a curve suited to the purposes of a bridge or an arcade, which requires an outline nearly horizontal.

Examp. 2. Let the curve be a parabola AVE (fig. 11.), of which V is the vertex, and DG the directrix. Draw the diameters DCF , GVN , the tangents CK , VP , and the ordinates VF and CN . It is well known that GV is to DC as VP^2 to CK^2 , or as CN^2 to CK^2 . Also $2GV$ is the radius of the osculating circle at V , and $2DC$ is one-half of the vertical cord of the osculating circle at C . Therefore $CN^2 : CK^2$ (or $y^2 : z^2$) = $R : s$, and $s = \frac{z^2}{y^2} R$. But Cc , or $b = H \times \frac{z^2}{y^2} \frac{R}{S}$. Therefore $b = H \times \frac{z^2}{y^2} \frac{R}{\frac{z^2}{y^2} R} = H \times \frac{z^2}{z^2} \frac{R}{R} = H$. Therefore $Cc = vV$.

It follows from this investigation, that the back or extrados of a parabolic arch of equilibration must be parallel to the arch or soffit itself; or that the thickness of the arch, estimated in a vertical direction, must be equal throughout; or that the extrados is the same parabola with the soffit or intrados.

We have selected these two examples merely for the simplicity and perspicuity of the solutions, which have been effected by means of elementary geometry only, instead of employing the analytical value of the radius of the osculatory circle, viz. $\frac{z^3}{y^2 x - x^2 y}$, which would have involved us at least in the elements of second fluxions. We have also preferred simplicity to elegance in the investigation, because we wish to instruct the practical engineer, who may not be a proficient in the higher mathematics.

The converse of the problem, namely, to find the form of the arch when the figure of the back of it is given, is the most usual question of the two, at least in these perhaps bridges are the chief. Here the necessity of a road-way, of easy and regular ascent, confines us to an outline nearly horizontal, to which the curve of the arch must be adapted. This is the most difficult problem of the two; and we doubt whether it can be solved without employing infinite approximating series instead of accurate values.

Let ave (fig. 12.) be the intended outline or extrados of the arch AVE , and let vQ be the common axis of both curves. From c and C , the corresponding points, draw the ordinates cb , CH . Let the thickness vV at the top be a , the abscissa vb be x , and VH be y , and let the equal ordinates cb , CH be y , and the arch VC be z .

Then, by the general theorem, $cC = \frac{z^3}{r y^3}$, r being the radius of curvature. This, by the common rules, is

$$= \frac{z^3}{y^2 x - x^2 y} \quad \text{This gives us } cC = \frac{y^2 \ddot{x} - x^2 \ddot{y}}{y^3}, \text{ or}$$

$$= \frac{y^2 \ddot{x} - x^2 \ddot{y}}{y^3} \times C; \text{ where } C \text{ is a constant quantity,}$$

found by taking the real value of cC in V , the vertex of the curve. But it is evident that it is also $a + x$

$$- u. \text{ Therefore } a + x - u = \frac{y^2 \ddot{x} - x^2 \ddot{y}}{y^3} \times C = \frac{C}{y} \times \text{fluxion of } \frac{x}{y}.$$

If we now substitute the true value of u (which is given, because the extrados is supposed to be of a known form), expressed in terms of y , the resulting equation will contain nothing but x and y , with their first and second fluxions, and known quantities. From this equation the relation of x and y must be found by such methods as seem best adapted to the equation of the extrados.

Fortunately the process is more simple and easy in the most common and useful case than we should expect from this general rule. We mean the case where the extrados is a straight line, especially when this is horizontal. In this case u is equal to o .

Example. To find the form of the balanced arch AVE (fig. 13.), having the horizontal line cv for its extrados. Plate II

Keeping the same notation, we have $u = o$, and therefore $a + x = \frac{C}{y} \times \text{fluxion of } \frac{x}{y}$.

$$\text{Assume } \dot{y} = \frac{x}{v}; \text{ then } \frac{x}{y} = v, \text{ and } \frac{C}{y} \times \text{fluxion of } \frac{x}{y} = \frac{Cv\dot{v}}{x}, \text{ that is } a + x = \frac{Cv\dot{v}}{x}.$$

$$\text{Therefore } ax + x^2 = Cv\dot{v}; \text{ and by taking the fluents, we have } 2ax + x^2 = Cv^2; \text{ and } v = \sqrt{\frac{2ax + x^2}{C}}.$$

Consequently,

$$y = \frac{\sqrt{Cx}}{\sqrt{2ax + x^2}} \left(\text{being } = \frac{x}{v} \right).$$

Taking the fluent of this, we have $y = \sqrt{C} \times L(2ax + x^2)$

Arch. $+ 2\sqrt{2ax + x^2}$. But at the vertex, where $x = 0$, we have $y = \sqrt{C \times L(2a)}$. The corrected fluent is therefore $y = \sqrt{C \times L \frac{a + x + \sqrt{2ax + x^2}}{a}}$.

It only remains to find the constant quantity C. This we readily obtain by selecting some point of the extrados where the values of x and y are given by particular circumstances of the case. Thus, when the span $2s$ and height b of the arch are given, we have

$$s = \sqrt{C \times L \left(\frac{a + b + \sqrt{2ab + b^2}}{a} \right)}, \text{ and conse-}$$

$$\text{quently } \sqrt{C} = \frac{s}{L \left(\frac{a + b + \sqrt{2ab + b^2}}{a} \right)}. \text{ Therefore}$$

$$\text{the general value of } y = s \times \frac{L \left(\frac{a + x + \sqrt{2ax + x^2}}{a} \right)}{L \left(\frac{a + b + \sqrt{2ab + b^2}}{a} \right)};$$

$$= \frac{s}{L \frac{a + b + \sqrt{2ab + b^2}}{a}} \times L \frac{a + x + \sqrt{2ax + x^2}}{a}.$$

As an example of the use of this formula, we subjoin a table calculated by Dr Hutton of Woolwich for an arch, the span of which is 100 feet, and the height 40; which are nearly the dimensions of the middle arch of Blackfriars Bridge in London.

y	x	y	x	y	x
0	6,000	21	10,381	36	21,774
2	6,035	22	10,858	37	22,948
4	6,144	23	11,368	38	24,190
6	6,324	24	11,911	39	25,505
8	6,580	25	12,489	40	26,894
10	6,914	26	13,106	41	28,364
12	7,330	27	13,761	42	29,919
13	7,571	28	14,457	43	31,563
14	7,834	29	15,196	44	33,299
15	8,120	30	15,980	45	35,135
16	8,430	31	16,811	46	37,075
17	8,766	32	17,693	47	39,126
18	9,168	33	18,627	48	41,293
19	9,517	34	19,617	49	43,581
20	9,934	35	20,665	50	46,000

The figure for this proposition is exactly drawn according to these dimensions, that the reader may judge of it as an object of sight. It is by no means deficient in gracefulness, and is abundantly roomy for the passage of craft; so that no objection can be offered against its being adopted on account of its mechanical excellency.

The reader will perhaps be surprised that we have made no mention of the celebrated Catenarian curve, which is commonly said to be the best form for an arch; but a little reflection will convince him, that although it is the only form for an arch consisting of stones of equal weight, and touching each other only in single points, it cannot suit an arch which must be filled up in the haunches, in order to form a road-way. He will be more surprised to hear, after this, that there is a certain thickness at the crown, which will put the Catenaria in equilibrio, even with a horizontal road-way;

but this thickness is so great as to make it unfit for a bridge, being such that the pressure at the vertex is equal to the horizontal thrust. This would have been about 37 feet in the middle arch of Blackfriars Bridge. The only situation, therefore, in which the Catenarian form would be proper, is an arcade carrying a height of dead wall; but in this situation it would be very ungraceful. Without troubling the reader with the investigation, it is sufficient to inform him that in a Catenarian arch of equilibration the abscissa VH is to the abscissa v b in the constant ratio of the horizontal thrust to its excess above the pressure on the vertex.

This much will serve, we hope, to give the reader a clear notion of this celebrated theory of the equilibrium of arches, one of the most delicate and important applications of mathematical science. ²⁷ Volumes have been written on the subject, and it still occupies the attention of mechanicians. But we beg leave to say, with great deference to the eminent persons who have professed this theory, that their speculations have been of little service, and are little attended to by the practitioner. Nay, we may add, that Sir Christopher Wren, perhaps the most accomplished architect that Europe has seen, seems to have thought it of little value: for, among the fragments which have been preserved of his studies, there are to be seen some imperfect dissertations on this very subject, in which he takes no notice of this theory, and considers the balance of arches in quite another way. These are collected by the author of the account of Sir Christopher Wren's family. This man's great sagacity, and his great experience in building, and still more his experience in the repairs of old and crazy fabrics, had shewn him many things very inconsistent with this theory, which appears so specious and safe. The general facts which occur in the failure of old arches are highly instructive, and deserve the most careful attention of the engineer; for it is in this state that their defects, and the process of nature in their destruction, are most distinctly seen. We venture to affirm, that a very great majority of these facts are irreconcilable to the theory. The way in which circular arches commonly fail, is by the sinking of the crown and the rising of the flanks. It will be found by calculation, that in most of the cases it ought to have been just the contrary. But the clearest proof is, that arches very rarely fail where their load differs most remarkably from that which this theory allows. Semicircular arches have stood the power of ages, as may be seen in the bridges of ancient Rome, and in the numerous arcades which the ancient inhabitants have erected. Now all arches which spring perpendicularly from the horizontal line, require, by this theory, a load of infinite height; and, even to a considerable distance from the springing of the arch, the load necessary for the theoretical equilibrium is many times greater than what is ever laid on those parts; yet a failure in the immediate neighbourhood of the spring of an arch is a most rare phenomenon, if it ever was observed. Here is a most remarkable deviation from the theory; for, as is already observed, the load is frequently not the fourth part of what the theory requires.

Many other facts might be adduced which shew great deviations from the legitimate results from the theory. We hope to be excused, therefore, by the mathematicians for doubting of the justness of this theory. We

26
Defects of
the Cate-
rian curve.

Arch. do not think it erroneous, but defective, leaving out
 28 Its defects. circumstances which we apprehend to be of great im-
 portance; and we imagine that the defects of the theory
 have arisen from the very anxiety of the mechanicians
 to make it perfect. The arch-stones are supposed to
 be perfectly smooth or polished, and not to be connect-
 ed by any cement, and therefore to sustain each other
 merely by the equilibrium of their vertical pressure.
 The theory ensures this equilibrium, and this only,
 leaving unnoticed any other causes of mutual action.

The authors who have written on the subject say ex-
 pressly, that an arch which thus sustains itself must be
 stronger than another which would not; because when,
 in imagination, we suppose both to acquire connection
 by cement, the first preserves the influence of this con-
 nection unimpaired; whereas in the other, part of the
 cohesion is wasted in counteracting the tendency of
 some parts to break off from the rest by their want of
 equilibrium. This is a very specious argument, and
 would be just, if the forces which are mutually exerted
 between the parts of the arch in its settled state were
 merely vertical pressures, or, where different, were in-
 considerable in comparison with those which are really
 attended to in the construction.

But this is by no means the case. The forms which
 the uses for which arches are erected oblige us to adopt,
 and the loads laid on the different points of the arch,
 frequently deviate considerably from what are necessary
 for the equilibrium of vertical pressures. The varying
 load on a bridge, when a great wagon passes along it,
 sometimes bears a very sensible proportion to the weight
 of that point of the arch on which it rests. It is even
 very doubtful whether the pressures which are occa-
 sioned by the weight of the stuff employed for filling up
 the flanks really act in a vertical direction, and in the
 proportion which is supposed. We are pretty certain
 that this is not the case with sand, gravel, fat mould,
 and many substances in very general use for this pur-
 pose. When this is the case, the pressures sustained
 by the different parts of the arch are often very incon-
 sistent with the theory—a part of the arch is over-
 loaded, and tends to fall in, but is prevented by the ce-
 ment. This part of the arch therefore acts on the re-
 moter parts by the intervention of the parts between,
 employing those intermediate parts as a kind of levers
 to break the arch in a remote part, just as a lintel would
 be broken. We apprehend that a mathematician would
 be puzzled how to explain the stability of an arch cut
 out of a solid and uniform mass of rock. His theory
 considers the mutual thrusts of the arch stones as in the
 direction of the tangents to the arch. Why so? be-
 cause he supposes that all his polished joints are perpen-
 dicular to those tangents. But in the present case he
 has no existing joints; and there seems to be nothing to
 direct his imagination in the assumption of joints, which,
 however, are absolutely necessary for employing his
 theory, because, without a supposition of this kind, there
 seems no conceiving any mutual abutment of the arch
 stones. Ask a common, but intelligent, mason what
 notion he forms of such an arch? We apprehend that
 he will consider it as no arch, but as a lintel, which
 may be broken like a wooden lintel, and which resists
 entirely by its cohesion. He will not readily conceive
 that, by cutting the under side of a stone lintel into an
 arched form, and thus taking away more than half of

Arch. its substance, he has changed its nature of a lintel, or
 given it any additional strength. Nor would there be
 any change made in the way in which such a mass of
 stone would resist being broken down, if nothing were
 done but forming the under side into an arch. If the
 lintel be so laid on the piers that it can be broken with-
 out its parts pushing the piers aside (which will be the
 case if it lies on the piers with horizontal joints), it will
 break like any other lintel; but if the joints are direct-
 ed downwards, and converging to a point within the
 arch, the broken stone (suppose it broken at the crown
 by an overload in that part) cannot be pressed down
 without forcing the piers outwards. Now, in this mode
 of acting, the mind cannot trace any thing of the sta-
 tical equilibrium that we have proceeded on in the
 foregoing theory. The two parts of the broken lintel
 seem to push the piers aside in the same manner that
 two rafters push outwards the walls of a house, when
 their feet are not held together by a tie-beam. If the
 piers cannot be pushed aside (as when the arch abuts
 on two solid rocks), nothing can press down the crown
 which does not crush the stone.

This conclusion will be strictly true if the arch is of
 such a form that a straight line drawn from the crown
 to the pier lies wholly within the solid masonry. Thus
 if the vault consist of two straight stones, as in fig. 1.
 or if it consist of several stones, as in fig. 4. disposed
 in two straight lines, no weight laid on the crown can
 destroy it in any other way but by crushing it to pow-
 der.

But when straight lines cannot be drawn from the
 overloaded part to the firm abutments through the so-
 lid masonry, and when the cohesion of the parts is not
 able to withstand the transverse strains, we must call the
 principles of equilibrium to our aid; and in order to
 employ them with safety, we must consider how they
 are modified by the excitement of the cohering forces.

The cohesion of the stones with each other by ce-
 ment or otherwise, has, in almost every situation, a bad
 effect. It enables an overload at the crown to break
 the arch near the haunches, causing those parts to rise,
 and then to spread outwards, just as a Mansarde or
 Kirb roof would do if the truss beam which connects
 the heads of the lower rafters were sawn through. This
 can be prevented only by loading that part more than
 is requisite for equilibrium. It would be prudent to do
 this to a certain degree, because it is by this cohesion
 that the crown always becomes the weakest part of the
 arch, and suffers more by any occasional load.

We expect that it will be said in answer to all this,
 that the cohesion given by the strongest cement that
 we can employ, nay, the cohesion of the stone itself, is
 a mere nothing in comparison with the enormous thrusts
 that are in a state of continual exertion in the different
 parts of an arch. This is very true; but there is an-
 other force which produces the same effect, and which
 increases nearly in the proportion that those thrusts in-
 crease, because it arises from them. This is the friction
 of the stones on each other. In dry freestone this fric-
 tion considerably exceeds one half of the mutual pres-
 sure. The reflecting reader will see that this produces
 the same effect, in the case under consideration, that
 cohesion would do; for while the arch is in the act of
 failing, the mutual pressure of the arch-stones is acting
 with full force, and thus produces a friction more than
 adequate

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 When it is
 to be called
 into the aid
 of the build-
 der.

Arch. adequate to all the effects we have been speaking of.

³⁰
Process of
the break-
ing of an
arch.

When these circumstances are considered, we imagine that it will appear that an arch, when exposed to a great overload on the crown (or indeed on any part), divides, of itself, into a number of parts, each of which contains as many arch-stones as can be pierced (so to speak) by one straight line, and that it may then be considered as nearly in the same situation with a polygonal arch of long stones butting on each other like so many beams in a Norman roof (see Roof, n^o 49.), but without their braces and ties. It tends to break at all those angles; and it is not sufficiently resisted there, because the materials with which the flanks are filled up have so little cohesion, that the angle feels no load except what is immediately above it; whereas it should be immediately loaded with all the weight which is diffused over the adjoining side of the polygon. This will be the case, even though the curvilinear arch be perfectly equilibrated. We recollect some circumstances in the failure of a considerable arch, which may be worth mentioning. It had been built of an exceedingly soft and friable stone, and the arch stones were too short. About a fortnight before it fell, chips were observed to be dropping off from the joints of the archstones about ten feet on each side of the middle, and also from another place on one side of the arch, about twenty feet from its middle. The masons in the neighbourhood prognosticated its speedy downfall, and said that it would separate in those places where the chips were breaking off. At length it fell; but it first split in the middle, and about 15 or 16 feet on each side, and also at the very springing of the arch. Immediately before the fall a shivering or crackling noise was heard, and a great many chips dropped down from the middle between the two places from whence they had dropped a fortnight before. The joints opened above at those new places above two inches, and in the middle of the arch the joints opened below, and in about five minutes after this the whole came down. Even this movement was plainly distinguishable into two parts. The crown sunk a little, and the haunches rose very sensibly, and in this state it hung for about half a minute. The arch-stones of the crown were hanging by their upper corners. When these splintered off, the whole fell down.

We apprehend that the procedure of nature was somewhat in this manner. Straight lines can be drawn within the arch-stones from A (fig. 15.) to B and D, and from those points to C and E. Each of the portions ED, DA, AB, EC, resist as if they were of one stone, composing a polygonal vault EDABC. When this is overloaded at A, A can descend in no other way than by pushing the angles B and D outwards, causing the portions BC, DE, to turn round C and E. This motion must raise the points B and D, and cause the arch-stones to press on each other at their *inner* joints *b* and *d*. This produced the copious splintering at those joints immediately preceding the total downfall. The splintering which happened a fortnight before arose from this circumstance, that the lines AB and AD, along which the pressure of the overload was propagated, were tangents to the soffit of the arch in the points F, H, and G, and therefore the strain lay all on those corners of the arch-stones, and splintered a little

from off them till the whole took a firmer bed. The subsequent phenomena are evident consequences of this distribution and modification of pressure, and can hardly be explained in any other way; at least not on the theoretical principles already set forth: for in this bridge the loads at B and D were very considerably greater than what the equilibrium required; and we think that the first observed splintering at H, F, and G, was most instructive, showing that there was an extraordinary pressure at the inner joints in those places, which cannot be explained by the usual theory.

Arch.

Not satisfied with this single observation, after this way of explaining it occurred to us, and not being able to find any similar fact on record, the writer of this article got some small models of arches executed in chalk, and subjected them to many trials, in hopes of collecting some general laws of the internal workings of arches which finally produce their downfall. He had the pleasure of observing the above mentioned circumstances take place very regularly and uniformly, when he overloaded the models at A. The arch always broke at some place B considerably beyond another point F, where the first chipping had been observed. This is a method of trial that deserves the attention both of the speculatist and the practitioner.

If these reflections are any thing like a just account of the procedure of nature in the failure of an arch, it is evident that the ingenious mathematical theory of equilibrated arches is of little value to the engineer. We ventured to say as much already, and we rested a good deal on the authority of Sir Christopher Wren. He was a good mathematician, and delighted in the application of this science to the arts. He was a celebrated architect; and his reports on the various works committed to his charge, show that he was in the continual habit of making this application. Several specimens remain of his own methods of applying them. The roof of the theatre of Oxford, the roof of the cupola of St Paul's, and in particular the mould on which he turned the inner dome of that cathedral, are proofs of his having studied this theory most attentively. He flourished at the very time that it occupied the attention of the greatest mechanics of Europe; but there is nothing to be found among his papers which shows that he had paid much regard to it. On the contrary, when he has occasion to deliver his opinion for the instruction of others, and to explain to the Dean and Chapter of Westminster his operations in repairing that collegiate church, this great architect considers an arch just as a sensible and sagacious mason would do, and very much in the way that we have just now been treating it: (See *Account of the Family of Wren*, p. 356, &c.) Supported therefore by such authority, we would recommend this way of considering an arch to the study of the mathematician; and we would desire the experienced mason to think of the most efficacious methods for resisting this tendency of arches to rise in the flanks. Unfortunately there seems to be no precise principle to point out the place where this tendency is most remarkable.

We are therefore highly pleased with the ingenious contrivance of Mr Mylne, the architect of Blackfriars Bridge in London, by which he determines this point with precision, by making it impossible for the overloaded arch to spring in any other place. Having thus

confined.

Arch. confined the failure to a particular spot, he with equal art opposes a resistance which he believes to be sufficient; and the present condition of that noble bridge, which does not in any place show the smallest change of shape, proves that he was not mistaken. Looking on this work as the first, or at least the second, specimen of masonic ingenuity that is to be seen in the world, we imagine that our readers will be pleased with a particular account of its most remarkable circumstances.

31
Construction of
Blackfriars
Bridge.
Plate III.

The span $k a$ (fig. 16.) of the middle arch is 100 feet, and its height OV is 40, and the thickness KV of the crown is six feet seven inches. Its form is nearly elliptical; the part AVZ being an arch of a circle whose centre is C , and radius 56 feet, and the two lateral portions $A k B$ and $Z a E$ being arches described with a radius of 35 feet nearly. The thickness of the pier at $a b$ is 19 feet. The thickness of the arch increases from the crown V to Y , where it is eight or nine feet. All the arch-stones have their joints directed to the centres of their curvature. The joints are all joggled, having a cubic foot of hard stone let half way into each. By this contrivance the joints cannot slide, nor can any weight laid on the crown ever break the arch in that part, if the piers do not yield; for a straight line from the middle of KV to the middle of the joint YI is contained within the solid masonry, and does not even come near the inner joints of the arch-stones. Therefore the whole resists like one stone, and can be broken only by crushing it. The joint at Z is very nearly perpendicular to a line YF drawn to the outer edge of the foundation of the pier. By this it was intended to take off all tendency of the pressure on the joint $d Z$ to overset the pier; for if we suppose, according to the theory of equilibration, that this pressure is necessarily exerted perpendicularly to the joint, its direction passes through the fulcrum at F , round which it is thought that the pier must turn in the act of over-setting. This precaution was adopted in order to make the arch quite independent of the adjoining arches; so that although any of them should fall, this arch should run no risk.

Still farther to secure the independence of the arch, the following construction was practised to unite it into one mass, which should rise altogether. All below the line $a b$ is built of large blocks of Portland stone, dovetailed with found oak. Four places in each course are interrupted by equal blocks of a hard stone called *Kentish rag*, sunk half way in each course. These act as joggles, breaking the courses, and preventing them from sliding laterally.

The portion $a Y$ of the arch is joggled like the upper part. The interior part is filled up with large blocks of Kentish rag, forming a kind of coursed rubble-work, the courses tending to the centres of the arch. The under corner of each arch-stone projects over the one below it. By this form it takes fast hold of the rubble-work behind it. Above this rubble there is constructed the inverted arch $I e G$ of Portland stone. This arch shares the pressure of the two adjoining arches, along with the arch-stones in $Y a$ and in $G b$. Thus all tend together to compress and keep down the rubble-work in the heart of this part of the pier. This is a very useful precaution; for it often happens, that when the centres of the arches are struck, before the piers are

built up to their intended height, the thrust of the arches squeezes the rubble-work horizontally, after the mortar has set, but before it has dried and acquired its utmost hardness. Its bond is broken by this motion, and it is squeezed up, and never acquires its former firmness. This is effectually prevented by the pressure exerted by the back of the inverted arch.

Above this counter arch is another mass of coursed rubble, and all is covered by a horizontal course of large blocks of Portland stone, butting against the back of the arch-stone ZI and its corresponding one in the adjoining arch. This course connects the feet of the two arches, preserves the rubble-work from too great compression, and protects it from soaking water. This last circumstance is important; for if the water which falls on the road-way is not carried off in pipes, it soaks through the gravel or other rubbish, rests on the mortar, and keeps it continually wet and soft. It cannot escape through the joints of good masonry, and therefore fills up this part like a funnel.

Supposing the adjoining arch fallen, and all tumbled off that is not withheld by its situation, there will still remain in the pier a mass of about 3500 tons. The weight of the portion VY is about 2000 tons. The directions of the thrusts RY and YF are such, that it would require a load of 4500 tons on VY to overturn the pier round F . This exceeds VY by 2500 tons; a weight incomparably greater than any that can ever be laid on it.

Such is the ingenious construction of Mr Mylne. It evidently proceeds on the principles recommended above; principles which have occurred to his experience and sagacious mind during the course of his extensive practice. We have seen attempts by other engineers to withstand the horizontal thrusts of the arch by means of counter arches inserted in the same manner as here, but extending much farther over the main arch; but they did not appear to be well calculated for producing this effect. A counter arch springing from any point between Y and V has no tendency to hinder that point from rising by the sinking of the crown; and such a counter arch will not resist the precisely horizontal thrust so well as the straight course of Mr Mylne.

32
Origin of Gothic arches.

THE great incorporation of architects who built the cathedrals of Europe departed entirely from the styles of ancient Greece and Rome, and introduced another, in which arcades made the principal part. Not finding in every place quarries from which blocks could be raised in abundance of sufficient size for forming the far-projecting corniches of the Greek orders, they relinquished those proportions, and adopted a style of ornament which required no such projections: and having substituted arches for the horizontal architrave or lintel, they were now able to erect buildings of vast extent with spacious openings, and all this with very small pieces of stone. The form which had been adopted for a Christian temple occasioned many interfections of vaultings, and multiplied the arches exceedingly. Constant practice gave opportunities of giving every possible variety of these interfections, and taught the art of balancing arch against arch in every variety of situation. An art so multifarious, and so much out of the road of ordinary thought, could not but become an object of fond study to the architects most eminent for ingenuity

Arch. nuity and invention. Becoming thus the dupes of their own ingenuity, they were fond of displaying it even when not necessary. At last arches became their principal ornament, and a wall or ceiling was not thought dressed out as it should be till filled full of mock arches, crossing and butting on each other in every direction. In this process in their ceilings they found that the projecting mouldings, which we now call the Gothic tracery, formed the chief supports of the roofs. The plane surfaces included between those ribs were commonly vaulted with very small stones, seldom exceeding six or eight inches in thickness. This tracery therefore was not a random ornament. Every rib had a position and direction that was not only proper, but even necessary. Habituated to this scientific arrangement of the mouldings, they did not deviate from it when they ornamented a smooth surface with mock arches; and in none of the highly ornamented *ancient* buildings will we find any false positions. This is by no means the case in many of the modern imitations of Gothic architecture, even by our best architects. Ignorant of the directing principle, or not attending to it, in their stucco work, they please the unskilled eye with pretty radiated figures; but in these we frequently see such abutments of mouldings as would infallibly break the arches, if these mouldings were really performing their ancient office, and supporting a vaulting of considerable extent. Nay, this began even before the Gothic style was finally abandoned. Several instances are to be found in the highly enriched vaultings of New College, and Christ Church in Oxford, in St George's Chapel at Windfor, and Henry the VII's Chapel in Westminster.

33
Degenera-
cy of that
style.

We call the middle ages rude and barbarous; but there was surely much knowledge in those who could execute such magnificent and difficult works. The working drafts which were necessary for such varieties of oblique interfections must have required considerable skill, and would at present occupy many very expensive volumes of *masons jewels* and *carpenters manuals*, and the like. All this knowledge was kept a profound secret by the corporation, and on its breaking up we had all to learn again.

34
Great skill
of the a-
ncient Gothic
architects.

There is no appearance, however, that those architects had studied the theory of equilibrated arches. They had adopted an arch which was very strong, and permitted considerable irregularities of pressure—we mean the pointed arch. The very deep mouldings with which it was ornamented, made the arch stones very long in proportion to the span of the arch. But they had studied the mutual thrust of arches on each other with great care; and they contrived to make every invention for this purpose become an ornament, so that the eye required it as a necessary part of the building. Thus we frequently see small buildings having buttresses at the sides. These are necessary in a large vaulted building, for withstanding the outward thrust of the vaulting; but they are useless when we have a flat ceiling within. Pinnacles on the heads of the buttresses are now considered as ornaments; but originally they were put there to increase the weight of the buttress; even the great tower, in the centre of a cathedral, which now constitutes its great ornament, is a load almost indispensably necessary, for enabling the four principal columns to withstand the combined thrust of the aisles, of the nave, and transepts. In short, the more

Arch. closely we examine the ornaments of this architecture, the more shall we perceive that they are essential parts, or derived from them by imitation: and the more we consider the whole style of it, the more clearly do we see that it is all deduced from the relish for arcades, indulged in the extreme, and pushed to the limit of possibility of execution.

THERE is another species of arch which must not be overlooked, namely, the *DOME* or *CUPOLA*, with all its varieties, which include even the pyramidal steeple or spire. 35
Dome or
cupola

It is evident that the erection of a dome is also a scientific art, proceeding on the principles of equilibration, and that these principles admit and require the same or similar modifications, in consequence of the cohesion and friction of the materials. At first sight, too, a dome appears a more difficult piece of work than a plain arch; but when we observe potters kilns and glasshouse domes and cones of vast extent, erected by ordinary bricklayers, and with materials vastly inferior in size to what can be employed in common arches of equal extent, we must conclude that the circumstance of curvature in the horizontal direction, or the abutment of a circular base, gives some assistance to the art. Of this we have complete demonstration in the case of the cone. We know that a vaulting in the form of a pent roof could not be executed to any considerable extent, and would be extremely hazardous, even in the smallest dimensions; while a cone of the greatest magnitude can be raised with very small stones, provided only that we prevent the bottom from flying out, by a hoop, or any similar contrivance. And when we think a little of the matter, we see plainly, that if the horizontal section be perfectly round, and the joints be all directed to the axis, they all equally endeavour to slide inwards, while no reason can be offered why any individual stone should prevail. They are all wedges, and operate only as wedges. When we consider any single course, therefore, we see that it cannot fall in, even though it may be part of a curve which could not stand as a common arch; nay, we see that a dome may be constructed having the convexity of the curve, by the revolution of which it is formed, turned towards the axis, so that the outline is concave. We shall afterwards find that this is a stronger dome by far than if the convexity were outwards, as in a common arch. We see also that a cone may be loaded on the top with the greatest weight, without the smallest danger of forcing it down, so long as the bottom course is firmly kept from bursting outwards. The stone lantern on the top of St Paul's cathedral in London weighs several hundred tons, and is carried by a brick cone of eighteen inches thick, with perfect safety, as long as the bottom course is prevented from bursting outwards. The reason is evident: The pressure on the top is propagated along the cone in the direction of the slant side; and, so far from having any tendency to break it in any part, it tends rather to prevent its being broken by any irregular pressure from foreign causes. 36
Of easier
construction than
a plain
arch.

For the same reasons the octagonal pyramids, which form the spires of Gothic architecture, are abundantly firm, although very thin. The sides of the spire of Salisbury cathedral are not eight inches thick after the octagon is fully formed. It is proper, however, to di- 37
Proper con-
struction of
octagonal
pyramids.

D rect

Arch.

rect the joints to the axis of the pyramid, and to make the coursing joints perpendicular to the slant side, because the projecting mouldings which run along the angles are the abutments on which the whole pannel depends. A considerable art is necessary for supporting those pannels or sides of the octagon which spring from the angles of the square tower. This is done by beginning a very narrow pointed arch on the square tower at a great distance below the top; so that the legs of the arch being very long, a straight line may be drawn from the top of the keystone of the arch through the whole archstones of the legs. By this disposition the thrusts arising from the weight of these four pannels are made to meet on the massive masonry in the middle of the sides of the tower, at a great distance below the springing of the spire. This part, being loaded with the great mass of perpendicular wall, is fully able to withstand the horizontal thrust from the legs of those arches. In many spires these thrusts are still farther resisted by iron bars which cross the tower, and are hooked into pieces of brass firmly bedded in the masonry of the sides.

38
Examples
of such con-
struction.

There is much nice balancing of this kind to be observed in the highly ornamented open spires; such as those of Brussels, Mechlin, Antwerp, &c. We have not many of this sort in Britain. In those of great magnitude, the judicious eye will discover that parts, which a common spectator would consider as mere ornaments, are necessary for completing the balance of the whole. Tall pinnacles, nay, even pillars carrying entablatures and pinnacles, are to be seen standing on the middle of the slender leg of an arch. On examination, we find that this is necessary, to prevent the arch from springing upwards in that place by the pressure at the crown. The steeple of the cathedral of Mechlin was the most elaborate piece of architecture in this taste in the world, and was really a wonder; but it was not calculated to withstand a bombardment, which destroyed it in 1578.

Such frequent examples of irregular and whimsical buildings of this kind, show that great liberties may be taken with the principle of equilibration without risk, if we take care to secure the base from being thrust outwards. This may always be done by hoops, which can be concealed in the masonry; whereas, in common arches, these ties would be visible, and would offend the eye.

It is now time to attend to the principle of equilibrium, as it operates in a simple circular dome, and to determine the thickness of the vaulting when the curve is given, or the curve when the thickness is given. Therefore, let BbA (fig. 17.) be the curve which produces the dome by revolving round the vertical axis AD . We shall suppose this curve to be drawn through the middle of all the arch-stones, and that the coursing or horizontal joints are every where perpendicular to the curve. We shall suppose (as is always the case) that the thickness $KL, HI, &c.$ of the arch-stones is very small in comparison with the dimensions of the arch. If we consider any portion HAh of the dome, it is plain that it presses on the course, of which HL is an arch-stone, in a direction bC perpendicular to the joint HI , or in the direction of the next superior element βb of the curve. As we proceed downwards, course after-course, we see plainly that this direction must

change, because the weight of each course is superadded to that of the portion above it, to complete the pressure on the course below. Through B draw the vertical line BCG , meeting βb , produced in C . We may take bc to press the pressure of all that is above it, propagated in this direction to the joint KL . We may also suppose the weight of the course HL , united in b , and acting on the vertical. Let it be represented by bF . If we form the parallelogram $bFGC$, the diagonal bG will represent the direction and intensity of the whole pressure on the joint KL . Thus it appears that this pressure is continually changing its direction, and that the line, which will always coincide with it, must be a curve concave downward. If this be precisely the curve of the dome, it will be an equilibrated vaulting; but so far from being the strongest form, it is the weakest, and it is the limit to an infinity of others, which are all stronger than it. This will appear evident, if we suppose that bG does not coincide with the curve AbB , but passes without it. As we suppose the arch-stones to be exceedingly thin from inside to outside, it is plain that this dome cannot stand, and that the weight of the upper part will press it down, and spring the vaulting outwards at the joint KL . But let us suppose, on the other hand, that bG falls within the curvilinear element bB . This evidently tends to push the arch-stone inward, towards the axis, and would cause it to slide in, since the joints are supposed perfectly smooth and slipping. But since this takes place equally in every stone of this course, they must all abut on each other in the vertical joints, squeezing them firmly together. Therefore, resolving the thrust bG into two, one of which is perpendicular to the joint KL , and the other parallel to it, we see that this last thrust is withstood by the vertical joints all around, and there remains only the thrust in the direction of the curve. Such a dome must therefore be firmer than an equilibrated dome, and cannot be so easily broken by overloading the upper part. When the curve is concave upwards, as in the lower part of the figure, the line bC always falls below bB , and the point C below B . When the curve is concave downwards, as in the upper part of the figure, bC passes above, or without bB . The curvature may be so abrupt, that even bG' shall pass without bB , and the point G' is above B' . It is also evident that the force which thus binds the stones of a horizontal course together, by pushing them towards the axis, will be greater in flat domes than in those that are more convex; that it will be still greater in a cone; and greater still in a curve whose convexity is turned inwards: for in this last case the line bG will deviate most remarkably from the curve. Such a dome will stand (having polished joints) if the curve springs from the base with any elevation, however small; nay, since the friction of two pieces of stone is not less than half of their mutual pressure, such a dome will stand, although the tangent to the curve at the bottom should be horizontal, provided that the horizontal thrust be double the weight of the dome, which may easily be the case if it do not rise high.

Thus we see that the stability of a dome depends on 40
very different principles from that of a common arch, from the
and is in general much greater. It differs also in another of a com-
very important circumstance, viz. that it may be mon arch
open in the middle: for the uppermost course, by tend-
ing

Plate II.

39
Stability of
a dome de-
pends on
principles

Arch.

Arch.

ing equally in every part to slide in toward the axis, presses all together in the vertical joints, and acts on the next course like the key stone of a common arch. Therefore an arch of equilibration, which is the weakest of all, may be open in the middle, and carry at top another building, such as a lantern, if its weight do not exceed that of the circular segment of the dome that is omitted. A greater load than this would indeed break the dome, by causing it to spring up in some of the lower courses; but this load may be increased if the curve is flatter than the curve of equilibration: and any load whatever, which will not crush the stones to powder, may be set on a truncate cone, or on a dome formed by a curve that is convex toward the axis; provided always that the foundation be effectually prevented from flying out, either by a hoop, or by a sufficient mass of solid pier on which it is set. We have mentioned the many failures which happened to the dome of St Sophia in Constantinople. We imagine that the thrust of the great dome, bending the eastern arch outward as soon as the pier began to yield, destroyed the half dome which was leaning on it, and thus, almost in an instant, took away the eastern abutment. We think that this might have been prevented without any change in the injudicious plan, if the dome had been hooped with iron, as was practised by Michael Angelo in the vastly more ponderous dome of St Peter's at Rome, and by Sir Christopher Wren in the cone and the inner dome of St Paul's at London. The weight of the latter considerably exceeds 3000 tons, and they occasion a horizontal thrust which is nearly half this quantity, the elevation of the cone being about 60°. This being distributed round the circumference, occasions a

bc , and complete the parallelogram $MONP$, and draw OQ perpendicular to the axis, and produce bF , cutting the ordinates in E and e . It is plain that MN is to MO as the weight of the arch HAb to the thrust bc which it exerts on the joint KL (this thrust being propagated through the course $HILK$); and that MQ , or its equal be , or δd , may represent the weight of the half AH .

Let AD be called x , and DB be called y . Then $be = \dot{x}$, and $eC = \dot{y}$ (because bc is in the direction of the element βb). It is also plain, that if we make \dot{y} constant, BC is the second fluxion of x , or $BC = \ddot{x}$, and be and BE may be considered as equal, and taken indiscriminately for \dot{x} . We have also $bc = \sqrt{x^2 + y^2}$. Let d be the depth or thickness HI of the arch-stones. Then $d \sqrt{x^2 + y^2}$ will represent the trapezium HL : and since the circumference of each course increases in the proportion of the radius y , $dy \sqrt{x^2 + y^2}$ will express the whole course. If \int be taken to represent the sum or aggregate of the quantities annexed to it, the formula will be analogous to the fluent of a fluxion, and $\int dy \sqrt{x^2 + y^2}$ will represent the whole mass, and also the weight of the vaulting down to the joint HI . Therefore we have this proportion $\int dy \sqrt{x^2 + y^2} : dy \sqrt{x^2 + y^2} = be : bF, = be : CG, = \delta d : CG, = \dot{x} : CG$. Therefore $CG = \frac{dy \dot{x} \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}}$.

If the curvature of the dome be precisely such as puts it in equilibrium, but without any mutual pressure in the vertical joints, this value of OG must be equal to CB , or to \dot{x} , the point G coinciding with B . This condition will be expressed by the equation $\frac{dy \dot{x} \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}} = \dot{x}$, or, more conveniently, by $\frac{dy \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}} = \frac{\dot{x}}{x}$.

But this form gives only a tottering equilibrium, independent of the friction of the joints and the cohesion of the cement. An equilibrium, accompanied by some firm stability, produced by the mutual pressure of the vertical joints, may be expressed by the formula $\frac{dy \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}}$

$> \frac{\dot{x}}{x}$, or by $\frac{dy \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}} = \frac{\dot{x}}{x} + \frac{i}{t}$, where t is some variable positive quantity, which increases when x increases. This last equation will also express the equilibrated dome, if t be a constant quantity, because in this case $\frac{i}{t}$ is $= 0$.

Since a firm stability requires that $\frac{dy \dot{x} \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}}$ shall be greater than \dot{x} , and CG must be greater than CB : Hence we learn, that figures of too great curvature, whose sides descend too rapidly, are improper. Also,

41
Excellency
of the dome
of St Paul's.

42
Theory of
the curves
proper for
domes.

strain on the hoop = $\frac{7}{2 \times 22}$ of the thrust, or nearly 238 tons. A square inch of the worst iron, if well forged, will carry 25 tons with perfect safety; therefore a hoop of 7 inches broad and $1\frac{1}{4}$ inches thick will completely secure this circle from bursting outwards. It is, however, much more completely secured; for besides a hoop at the base of very nearly these dimensions, there are hoops in different courses of the cone which bind it into one mass, and cause it to press on the piers in a direction exactly vertical. The only thrusts which the piers sustain are those from the arches of the body of the church and the transepts. These are most judiciously directed to the entering angles of the building, and are there resisted with insuperable force by the whole lengths of the walls, and by four solid masses of masonry in the corners. Whoever considers with attention and judgment the plan of this cathedral, will see that the thrusts of these arches, and of the dome, are incomparably better balanced than in St Peter's church at Rome. But to return from this sort of digression.

We have seen that if bG , the thrust compounded of the thrust bC , exerted by all the courses above $HILK$, and if the force bF , or the weight of that course, be everywhere coincident with bB , the element of the curve, we shall have an equilibrated dome; if it falls within it, we have a dome which will bear a greater load; and if it falls without it, the dome will break at the joint. We must endeavour to get analytical expressions of these conditions. Therefore draw the ordinates $b\delta b'$, BDB' , CdC' . Let the tangents at b and b' meet the axis in M , and make MO , MP , each equal to

Arch.

Arch.

since stability requires that we have $\frac{dy \dot{x} \sqrt{x^2 + y^2}}{\dot{x}}$ greater than $\int dy \sqrt{x^2 + y^2}$, we learn that the upper part of the dome must not be made very heavy. This, by diminishing the proportion of bF to bC , diminishes the angle cbG , and may set the point G above B , which will infallibly spring the dome in that place. We see here also, that the algebraic analysis expresses that peculiarity of dome-vaulting, that the weight of the upper part may even be supported.

The fluent of the equation $\frac{dy \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}} = \frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$

is most easily found. It is $L \int dy \sqrt{x^2 + y^2} = L \dot{x} + L t$, where L is the hyperbolic logarithm of the quantity annexed to it. If we consider y as constant, and correct the fluent so as to make it nothing at the vertex, it may be expressed thus, $L \int dy \sqrt{x^2 + y^2} - La = L \dot{x}$

$= L \dot{y} + L t$. This gives us $L \frac{\int dy \sqrt{x^2 + y^2}}{a} = \frac{L \dot{x}}{\dot{y}} t$,

and therefore $\frac{\int dy \sqrt{x^2 + y^2}}{a} = \frac{\dot{x}}{\dot{y}} t$.

This last equation will easily give us the depth of vaulting, or thickness d of the arch, when the curve is given. For its fluxion is $\frac{dy \sqrt{x^2 + y^2}}{a} = \frac{\dot{x} \dot{x} + \dot{t} \dot{x}}{\dot{y}}$,

and $d = \frac{a \dot{x} \dot{x} + a t \dot{x}}{y \dot{y} \sqrt{x^2 + y^2}}$, which is all expressed in known quantities; for we may put in place of t any power or function of x or of y , and thus convert the expression into another, which will still be applicable to all sorts of curves.

Instead of the second member $\frac{\ddot{x}}{\dot{x}} + \frac{\dot{t}}{t}$, we might employ $\frac{p \ddot{x}}{\dot{x}}$, where p is some number greater than unity.

This will evidently give a dome having stability; because the original formula $\frac{dy \dot{x} \sqrt{x^2 + y^2}}{\int dy \sqrt{x^2 + y^2}}$ will then be

greater than \ddot{x} . This will give $d = \frac{p a \dot{x} \dot{x} - \dot{x}}{y \dot{y} \sqrt{x^2 + y^2}}$. Each

of these forms has its advantages when applied to particular cases. Each of them also gives $d = \frac{a \dot{x}}{y \dot{y} \sqrt{x^2 + y^2}}$

when the curvature is such as is in precise equilibrium. And, lastly, if d be constant, that is, if the vaulting be of uniform thickness, we obtain the form of the curve, because then the relation of \ddot{x} to \dot{x} and to \dot{y} is given.

The chief use of this analysis is to discover what curves are improper for domes, or what portions of given curves may be employed with safety. Domes are generally built for ornament; and we see that there is great room for indulging our fancy in the choice. All curves which are concave outwards will give domes of great firmness: They are also beautiful. The Gothic

dome, whose outline is an undulated curve, may be made abundantly firm, especially if the upper part be convex and the lower concave outwards.

The chief difficulty in the case of this analysis arises from the necessity of expressing the weight of the incumbent part, or $\int dy \sqrt{x^2 + y^2}$. This requires the measurement of the conoidal surface, which, in most cases, can be had only by approximation by means of infinite serieses. We cannot expect that the generality of practical builders are familiar with this branch of mathematics, and therefore will not engage in it here; but content ourselves with giving such instances as can be understood by such as have that moderate mathematical knowledge which every man should possess who takes the name of engineer.

The surface of any circular portion of a sphere is very easily had, being equal to the circle described with a radius equal to the chord of half the arch. This radius is evidently $= \sqrt{x^2 + y^2}$.

In order to discover what portion of a hemisphere may be employed (for it is evident that we cannot employ the whole) when the thickness of the vaulting is uniform, we may recur to the equation or formula

$\frac{dy \dot{x} \sqrt{x^2 - y^2}}{\dot{x}} = \int dy \sqrt{x^2 + y^2}$. Let a be the radius of the hemisphere. We have $\dot{x} = \frac{a y \dot{y}}{\sqrt{a^2 - y^2}}$, and $\ddot{x} = \frac{a^2 \dot{y}^2}{a^2 - y^2}$.

Substituting these values in the formula, we obtain the equation $y^2 \sqrt{a^2 - y^2} = \int \frac{a^2 y \dot{y}}{\sqrt{a^2 - y^2}}$. We easily obtain the fluent of the second member $= a^3 -$

$a^2 \sqrt{a^2 - y^2}$, and $y = a \sqrt{-\frac{1}{2} + \sqrt{\frac{5}{4}}}$. Therefore if the radius of the sphere be one, the half breadth of the

dome must not exceed $\sqrt{-\frac{1}{2} + \sqrt{\frac{5}{4}}}$, or 0,786, and the height will be 618. The arch from the vertex is about $51^\circ 49'$. Much more of the hemisphere cannot stand, even though aided by the cement, and by the friction of the coursing joints. This last circumstance, by giving connection to the upper parts, causes the whole to press more vertically on the course below, and thus diminishes the outward thrust; but it at the same time diminishes the mutual abutment of the vertical joints, which is a great cause of firmness in the vaulting. A Gothic dome, of which the upper part is a portion of a sphere not exceeding 45° from the vertex, and the lower part is concave outwards, will be very strong, and not ungraceful.

But the public taste has long rejected this form, and seems rather to select more elevated domes than this portion of a sphere; because a dome, when seen from a small distance, always appears flatter than it really is. The dome of St Peter's is nearly an ellipsoid externally, of which the longer axis is perpendicular to the horizon. It is very ingeniously constructed. It springs from the base perpendicularly, and is very thick in this part. After rising about 50 feet, the vaulting separates into two thin vaultings, which gradually separate from each other. These two shells are connected together by thin partitions, which are very artificially dovetailed in both, and thus form a covering which is extremely stiff, while it is very light. Its great stiffness was necessary for enabling the crown of the dome to carry the elegant stone lantern

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Dome of St Peter's at Rome.

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lantern with safety. It is a wonderful performance, and has not its equal in the world; but it is an enormous load in comparison with the dome of St Paul's, and this even independent of the difference of size. If they were of equal dimensions, it would be at least five times as heavy, and is not so firm by its gravity; but as it is connected in every part by iron bars (lodged in the solid masonry, and well secured from the weather by having lead melted all round them), it bids fair to last for ages, if the foundations do not fail.

Plate II.

If a circle be described round a centre placed anywhere in the transverse axis AC (fig. 18. N^o 1.) of an ellipse, so as to touch the ellipse in the extremities B, b, of an ordinate, it will touch it internally, and the circular arch Bab will be wholly within the elliptical arch BAb. Therefore, if an elliptical and a spherical vaulting spring from the same base, at the same angle with the horizon, the spherical vaulting will be within the elliptical, will be flatter and lighter, and therefore the weight of the next course below will bear a greater proportion to the thrust in the direction of the curve; therefore the spherical vaulting will have more stability. On the contrary, and for similar reasons, an oblate elliptical vaulting is preferable to a spherical vaulting springing with the same inclination to the horizon. (Fig 18. N^o 2).

hemisphere, and may be broken off at any horizontal course, and then a similar or a greater portion of a smaller sphere may spring from this course as a base. It also bears being intersected by cylindrical vaultings in every direction, and the intersections are exact circles, and always have a pleasing effect. It also springs most gracefully from the heads of small piers, or from the corners of rooms of any polygonal shape; and the arches formed by its intersections with the walls are always circular and graceful, forming very handsome spandrels in every position. For these reasons Sir Christopher Wren employed it in all his vaultings, and he has exhibited many beautiful varieties in the transepts and the aisles of St Paul's, which are highly worthy of the observation of architects. Nothing can be more graceful than the vaultings at the ends of the north and south transepts, especially as finished off in the fine inside view published by Gwynn and Wale.

We conclude this article with observing, that the connection of the parts, arising from cement and from friction, has a great effect on dome-vaulting. In the same way as in common arches and cylindrical vaulting, it enables an overload on one place to break the dome in a distant place. But the resistance to this effect is much greater in dome-vaulting, because it operates all round the overloaded part. Hence it happens that domes are much less shattered by partial violence, such as the falling of a bomb or the like. Large holes may be broken in them without much affecting the rest; but, on the other hand, it greatly diminishes the strength which should be derived from the mutual pressure in the vertical joints. Friction prevents the sliding in of the arch stones which produces this mutual pressure in the vertical joints, except in the very highest courses, and even there it greatly diminishes it. These causes make a great change in the form which gives the greatest strength; and as their laws of action are but very imperfectly understood as yet, it is perhaps impossible, in the present state of our knowledge, to determine this form with tolerable precision. We see plainly, however, that it allows a greater deviation from the best form than the other kind of vaulting, and domes may be made to rise perpendicular to the horizon at the base, although of no great thickness; a thing which must not be attempted in a plane arch. The immense addition of strength which may be derived from hooping, largely compensates for all defects; and there is hardly any bounds to the extent to which a very thin dome-vaulting may be carried, when it is hooped or framed in the direction of the horizontal courses. The roof of the Halle du Bled at Paris is but a foot thick, and its diameter is more than 200, yet it appears to have abundant strength. It is, on the whole, a noble specimen of architecture.

46
Effects of cement and friction in dome vaulting.

44
Dimensions of the best form of a dome.

Persuaded, that what has been said on the subject convinces the reader that a vaulting perfectly equilibrated throughout is by no means the best form, provided that the base is secured from separating, we think it unnecessary to give the investigation of that form, which has a considerable intricacy; and shall content ourselves with merely giving its dimensions. The thickness is supposed uniform. The numbers in the first column of the table express the portion of the axis counted from the vertex, and those of the second column are the lengths of the ordinates.

AD	DB	AD	DB	AD	DB
0,4	100	610,4	1080	2990	1560
3,4	200	744	1140	3442	1600
11,4	300	904	1200	3972	1640
26,6	400	1100	1260	4432	1670
52,4	500	1336	1320	4952	1700
91,4	600	1522	1360	5336	1720
146,8	700	1738	1400	5756	1740
223,4	800	1984	1440	6214	1760
326,6	900	2270	1480	6714	1780
465,4	1000	2602	1520	7260	1800

The curve delineated in fig. 19. is formed according to these dimensions, and appears destitute of gracefulness; because its curvature changes abruptly at a little distance from the vertex, so that it has some appearance of being made up of different curves pieced together. But if the middle be occupied by a lantern of equal, or of smaller weight, this defect will cease, and the whole will be elegant, nearly resembling the exterior dome of St Paul's in London.

45
Advantages of dome-vaulting.

It is not a small advantage of dome-vaulting that it is lighter than any that can cover the same area. If, moreover, it be spherical, it will admit considerable varieties of figure, by combining different spheres. Thus, a dome may begin from its base as a portion of a large

We must not conclude this article without taking notice of that magnificent and elegant arch which has been erected in cast iron at Weremouth, near Sunderland, in the county of Durham. The inventor and architect is ROWLAND BURDON, Esq; one of the representatives of that county in the present Parliament.

47
The iron-bridge at Sunderland described.

This arch is a segment of a circle whose diameter is about 444 feet. The span or cord of the arch is 236 feet, and its versed sine or spring is 34 feet. It springs at the elevation of 60 feet from the surface of the river

river

Arch. ver at low water, so that vessels of 200 or perhaps 300 tons burden may pass under it in the middle of the stream, and even 50 feet on each side of it.

The sweep of the arch consists of a series of frames of cast iron, which butt on each other, in the same manner as the vouffoires of a stone arch. One of these frames or blocks (as we shall call them in future) is represented in fig. 1. as seen in front. It is cast in one piece; and consists of three pieces or arms BC, BC, BC, the middle one of which is two feet long, the upper being somewhat more, and the lower somewhat less, because their extremities are bounded by the radius drawn from the centre of the arch. These arms are four inches square, and are connected by other pieces KL, of such length that the whole length of the block is five feet in the direction of the radius. Each arm has a flat groove on each side, which is expressed by the darker shading, three inches broad and three-fourths of an inch deep. A section of this block, through the middle of KL, is represented by the light-shaded part BBB, in which the grooves are more distinctly perceived. These grooves are intended for receiving flat bars of malleable iron, which are employed for connecting the different blocks with each other. Fig. 2 represents two blocks united in this manner. For this purpose each arm has two square bolt-holes. The ends of the arms being nicely trimmed off, so that the three ends butt equally close on the ends of the next block; and the bars of hammered iron being also nicely fitted to their grooves, so as to fill them completely, and have their bolt holes exactly corresponding to those in the blocks, they are put together in such a manner that the joints or meetings of the malleable bars may fall on the middle between the bolt-holes in the arms. Flat headed bolts of wrought iron are then put through, and keys or forelocks are driven thro' the bolt-tails, and thus all is firmly wedged together, binding each arm between two bars of wrought iron. These bars are of such length as to connect several blocks.

In this manner a series of about 125 blocks are joined together, so as to form the precise curve that is intended. This series may be called a rib, and it stands in a vertical plane. The arch consists of six of these ribs, distant from each other five feet. These ribs are connected together so as to form an arch of 32 feet in breadth, in the following manner:

Fig. 3. represents one of the bridles or cross pieces which connect the different ribs, as it appears when viewed from below. It is a hollow pipe of cast iron, four inches in diameter, and has at each end two projecting shoulders, pierced with a bolt-hole near their extremities, so that the distance between the bolt-holes in the shoulders of one end is equal to the distance between the holes in the arms of the blocks, or the holes in the wrought iron bars. In the middle of the upper and of the under side of each end may be observed a square prominence, more lightly shaded than the rest. These projections also advance a little beyond the flat of the shoulders, forming between them a shallow notch, about an inch deep, which receives the iron of the arms, where they butt on each other, and thus gives an additional firmness to the joint. The manner in which the arms are thus grasped by these notches in the bridles is more distinctly seen in fig. 2. at the letter H in the middle of the upper rail.

The rib having been all trimmed and put together, so as to form the exact curve, the bolts are all taken out, and the horizontal bridles are then set on in their places, and the bolts are again put in and made fast by the forelocks. The bolts now pass through the shoulders of the bridles, through the wrought iron bars, and through the cast iron arm that is between them, and the forelocks bind all fast together. The manner in which this connection is completed is distinctly seen in fig. 2. which shews in perspective a double block in front, and a single block behind it. The butting joints of the two front blocks are at the letters E, E, E; the holes in the shoulders of the horizontal cross pieces are at H.

This construction is beautifully simple and very judicious. A vast addition of strength and of stiffness is procured by lodging the wrought iron bars in grooves formed in the cast iron rails; and for this purpose it is of great importance to make the wrought iron bars fill the grooves completely, and even to be so tight as to require the force of the forelocks to draw them home to the bottom of the grooves. There can be no doubt but that this arch is able to withstand an enormous pressure, as long as the abutments from which it springs do not yield. Of this there is hardly any risk, because they are masses of rock, faced with about four or five yards (in some places only) of solid block masonry. The mutual thrusts of the frames are all in the direction of the rails, so that no part bears any transverse strain. We can hardly conceive any force that can overcome the strength of those arms by pressure or crushing them. The manner in which the frames are connected into one rib, effectually secures the butting joints from slipping; and the accuracy with which the whole can be executed, secures us against any warping or deviation of a rib from the vertical plane.

But when we consider the prodigious span of this arch, and reflect that it is only five feet thick, it should seem that the most perfect equilibration is indispensably necessary. It is but like a film, and must be so supple that an overload on any part must have a great tendency to bend it, and to cause it to rise in a distant part; and this effect is increased by the very firmness with which the whole sticks together. The overloaded part acts on a distant part, tending to break it with all the energy of a long lever. This can be prevented only by means of the stiffness of the distant part. It is very true, the arch cannot break in the extrados except by tearing asunder the wrought iron bars which connect the blocks along the upper rail, and each of these requires more than a hundred tons to tear it asunder; yet an overload of five tons on any rib at its middle will produce this strain at twenty feet from the sides, supposing the sides held firm in their position. It were desirable therefore that something were done to stiffen the arch at the sides, by the manner of filling up the spandrels, or space between the arch and the roadway. This is filled up in a manner that is extremely light and pleasing to the eye, namely, by large cast iron circles, which touch the extrados of the arch and touch the roadway. The roadway rests on them as on so many hoops, while they rest on the back of the arch, and also touch each other laterally. We cannot think that this contributes to the strength of the arch; for these hoops will be easily compressed at the points of contact,

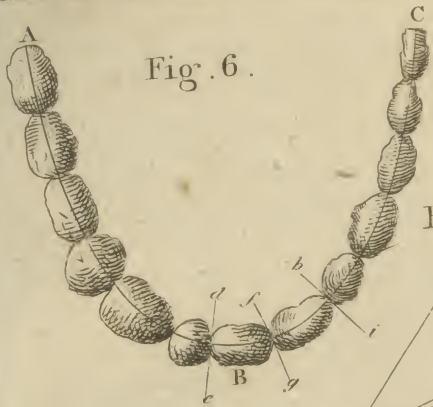
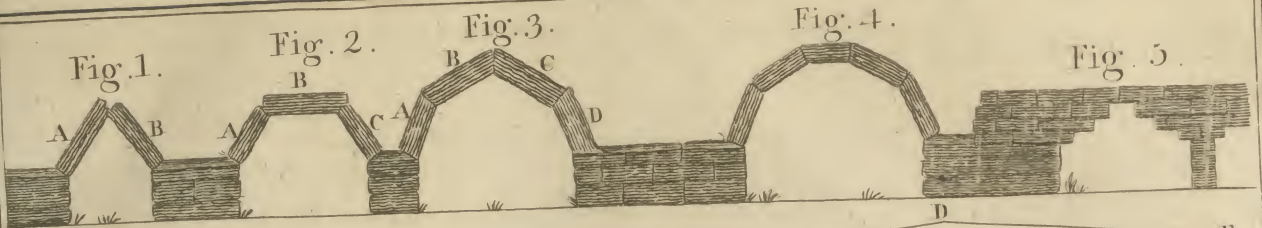


Fig. 6.

Fig. 8.

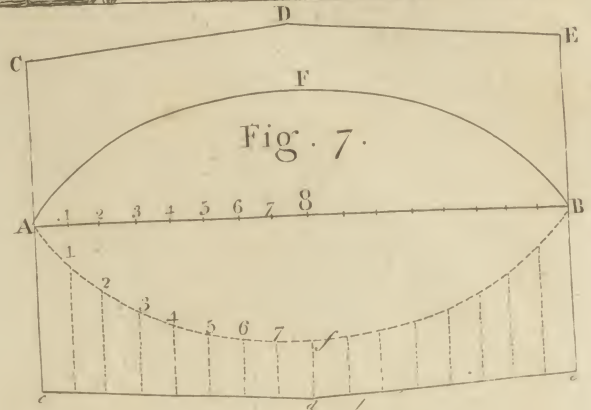
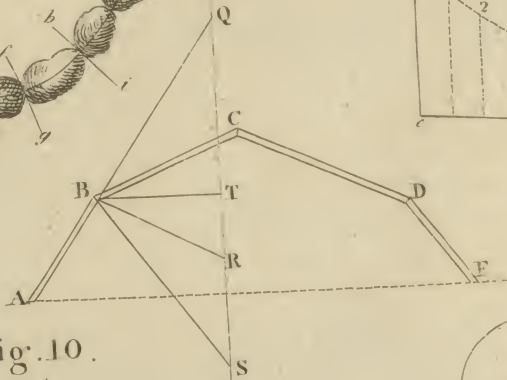


Fig. 7.

Fig. 9.

Fig. 10.

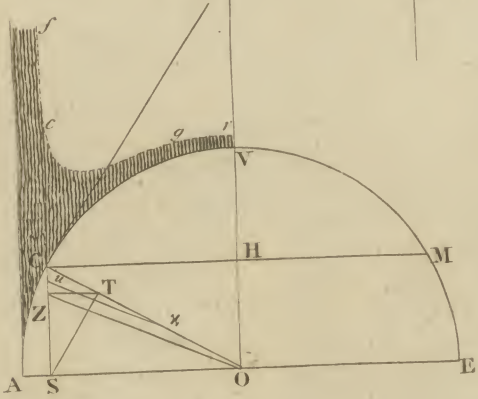


Fig. 11.

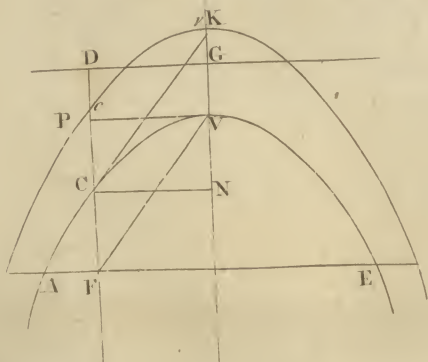
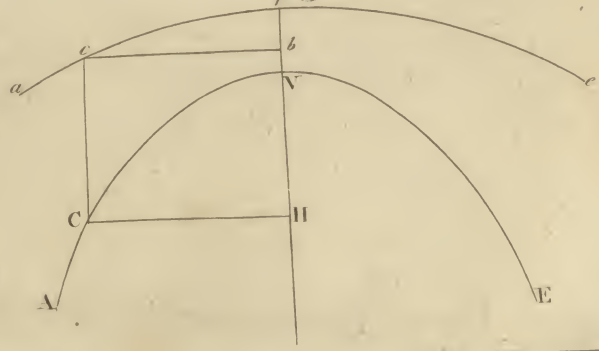


Fig. 12.



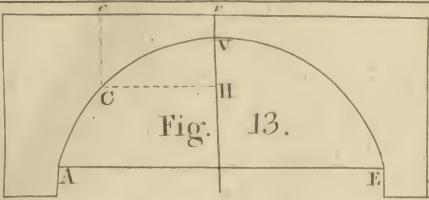


Fig. 13.

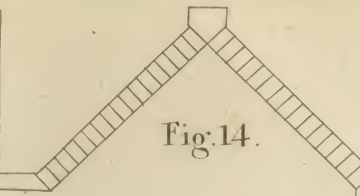


Fig. 14.

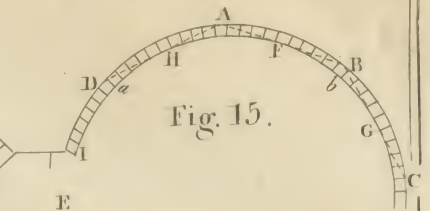


Fig. 15.

Fig. 18. N° 2.

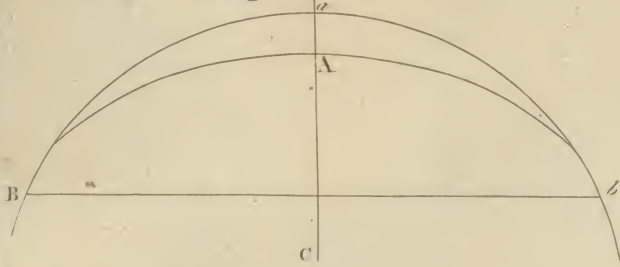


Fig. 19.

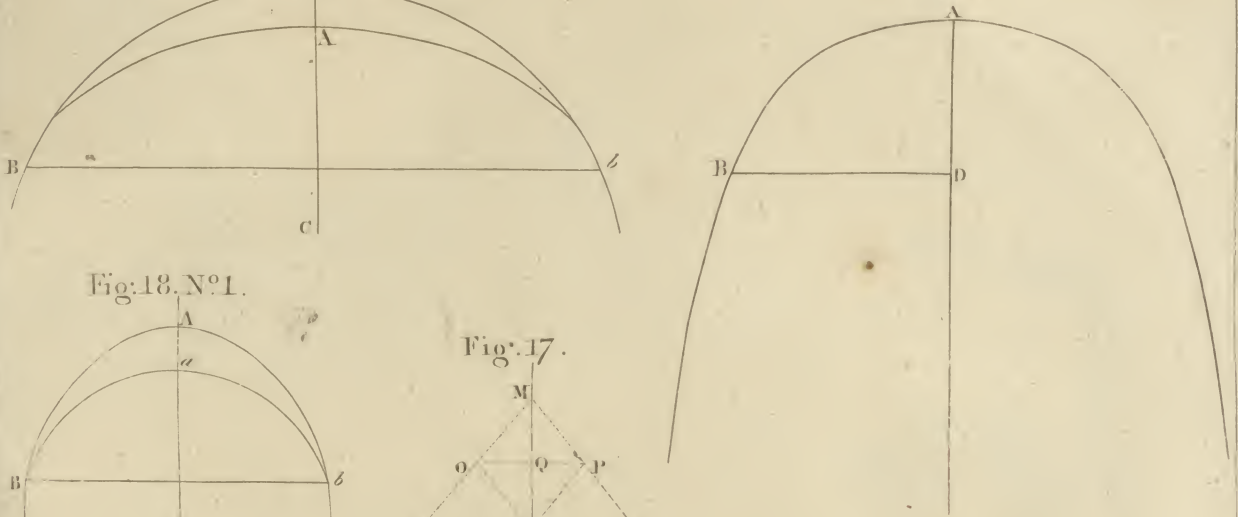


Fig. 18. N° 1.

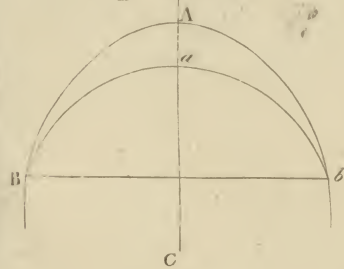


Fig. 17.

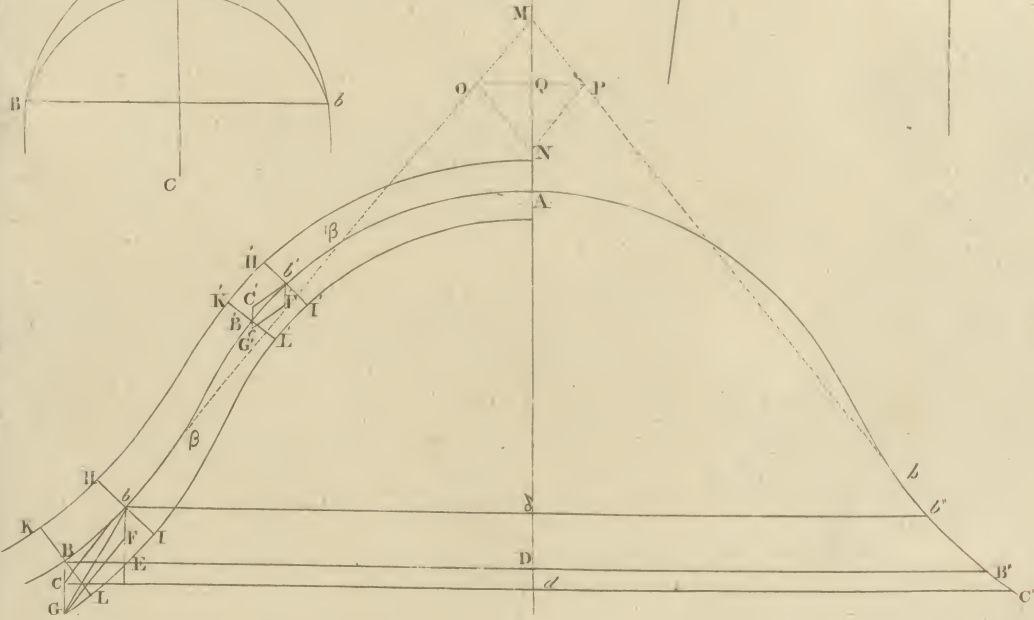


Fig. 2.

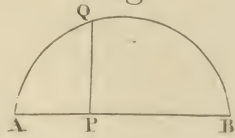


Fig. 3.

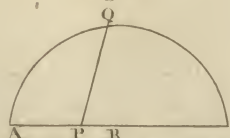


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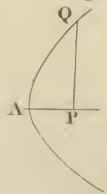


Fig. 5.

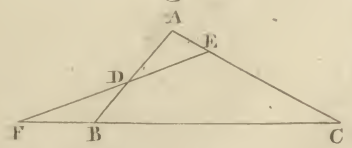
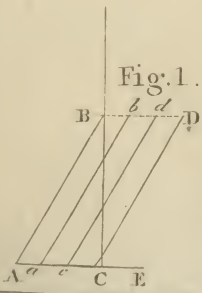
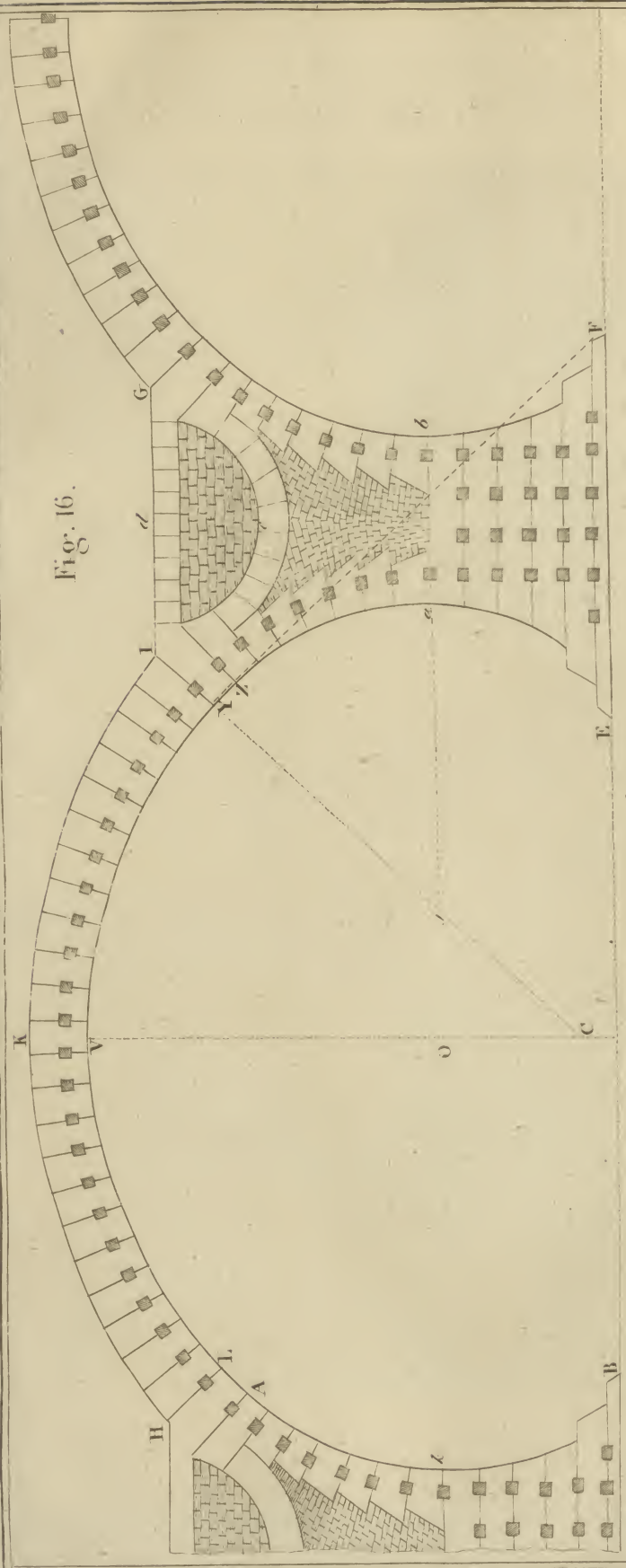


Fig. 1.





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IRON BRIDGE

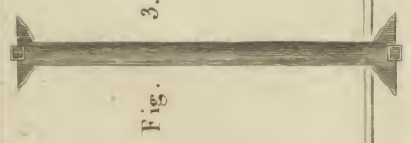


Fig. 3.

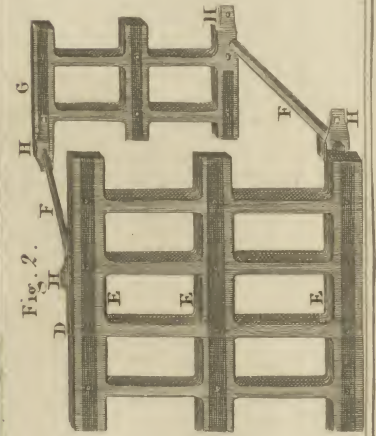


Fig. 2.

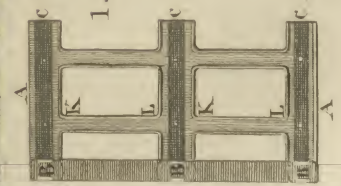


Fig. 1.



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contact, and, changing their shape, will oppose very little resistance. We think that this part of the arch might have been greatly stiffened and strengthened, by connecting it with the road-way by trussed frames, in the same way that a judicious carpenter would have framed a roof. If a strong cast iron pillar had been made to rest on the arch at about 20 feet from the impost, and been placed in the direction of a radius, the top of this pillar might have been connected by a diagonal bar of wrought iron with the impost of the arch, and with the crown of the arch by another string or bar of the same materials. These two ties would cause the radial pillar to press strongly on the back of the arch, and they must be torn asunder before it could bend in that place in the smallest degree. Supposing them of the same dimensions as the bars in the arms, their position would give them near ten times the force for resisting the strain produced by an overload on the crown.

This beautiful arch contains only 260 tons of iron, of which about 55 are wrought iron. The superstructure is of wood, planked over a-top. This floor is covered with a coating of chalk and tar, on which is laid the materials for the carriage road, consisting of marble, limestone, and gravel, with foot-ways of flag-stones at the sides. The weight of the whole did not exceed a thousand tons; whereas the lightest stone arch which could have been erected would have weighed fifteen thousand. It was turned on a very light but stiff scaffolding, most judiciously constructed for the preservation of its form, and for allowing an uninterrupted passage for the numerous ships and small craft which frequent the busy harbour of Sunderland. The mode of framing the arch was so simple and easy, that it was put up in ten days! without an accident; and when all was finished, and the scaffolding removed, the arch did not sensibly change its form. The whole work was executed in three years, and cost about L. 26,000.

ARCHITECTURE is an art of so much importance, and capable of so many embellishments, as to have employed the attention and talents of men of science in almost every age, and in every country. It is generally thought to have been carried to the utmost perfection among the Greeks and Romans; and it has been the aim of the most eminent architects of modern times to imitate with fidelity the buildings of those accomplished nations. There is, however, another species of architecture, which was introduced into Europe in the middle ages, and is of such a nature as to strike every unprejudiced observer with admiration and astonishment. The architecture to which we allude has been called, perhaps with little propriety,

Gothic ARCHITECTURE. It is that which is to be viewed in all our ancient cathedrals, and in other large buildings which have been erected from the middle of the 12th to the beginning of the 16th century. That such edifices have been constructed on principles of science, has been shewn elsewhere (see *ROOF*, *Encycl.* and *ARCH*, in this *Suppl.*): but a question still presents itself to the inquisitive mind, "How came such structures to be thought of by a people whom we are accustomed to call

ignorant and barbarous?" This question has occupied the attention of many ingenious men, who have attributed the Gothic style of building, some to necessity, and others to an imitation of the works of nature. That, where materials are bad, larger edifices can be erected in the Gothic than in the Grecian style, has been made sufficiently evident in the articles to which we have referred; and that necessity is the parent of invention, is an adage which has been too long received to be now called in question. But whence came the peculiarities of the Gothic ornaments in building, the pointed arch, and the double row of clustered pillars composed of slender shafts, which, reaching from the ground almost to the roof of the building, are there spread out in all directions, forming the ribs or *groins* of a vaulted roof?

The most satisfactory solution of this question which we have seen, is in a memoir published in the fourth volume of the *Transactions* of the Royal Society of Edinburgh, by Sir JAMES HALL, Bart. with whose permission the following abstract is laid before our readers.

"Although the connection between beauty and utility be still involved in such obscurity, that we are unable to decide concerning the universality of that connection, of one thing we are certain, that, in a work intended to answer some useful purpose, whatever visibly counteracts that purpose always occasions deformity. Hence it is, that, even where ornament is principally intended, the ostensibly useful object of the work, if it have any such, must be provided for, in the first place, in preference to every other consideration.

"But in most useful works, some parts occur, the shape of which is quite indifferent with respect to the proposed utility, and which, therefore, the artist is at liberty to execute as he pleases: a liberty which has opened a wide field to the taste and invention of ingenious men of every age and country, who have turned their attention to the composition of ornaments; and whose exertions have been more or less influenced by the state of civilization in which they lived. It would seem, however, if we may judge by those various efforts, that little has been effected by mere human ingenuity; since we see that recourse has been had, almost universally, to nature, the great and legitimate source of beauty; and that ornament has been attained by the imitation of objects, to which she has given a determinate and characteristic form.

"Where the materials employed are themselves possessed of variety and elegance, the attainment of this object requires little or no alteration of their natural forms. Thus cups are made of shells, of cocoa-nuts, or of ostrich eggs; the character and beauty of which depend upon the natural form of the materials: and in the case of the bottles used by the Roman Catholic pilgrims, an example occurs of an utensil, in which the natural form has undergone little or no variation, since it consists of the hard outward skin of a gourd, of the same shape in which it grew upon the plant (A). This last class of forms has been introduced, by imitation, into works composed

(A) "Even in this case, however, the natural form undergoes a certain degree of modification, by the device employed to produce the neck of the bottle. The fruit, while small and tender, is surrounded with a string, which remaining during its growth, prevents the part, thus bound, from swelling with the rest."

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composed of shapeless materials. Thus we have silver cups in the form of those made of shells, and fruit-dishes of stoneware in the form of baskets.

“As stone is not naturally possessed of any peculiar shape, and as the useful object proposed, by structures formed of it, may be accomplished, in various ways; very great latitude is left to the invention of the artist. We see, accordingly, that in every country where much refinement has been introduced, great pains have been bestowed in ornamenting stone buildings with figures representing various natural objects; whilst the building itself has been executed in imitation of a structure, composed of materials which naturally possess a determinate and characteristic form. Such was the method followed by the architects of ancient Greece, who constructed temples, and other public edifices, in imitation of a rustic fabric, composed of square beams, supported upon round posts or stems of trees, and who derived the numerous ornaments of that beautiful style from circumstances which would naturally take place in such a structure.

“A faint and distant resemblance, however, of the original, has generally been found to answer all the end proposed by the imitation; a resemblance, which may sometimes be traced in the general distribution of the edifice, sometimes in its minute parts, and not unfrequently in both.

“But the forms of nature thus introduced have been greatly modified by those of masonry. For though stone is by nature shapeless, yet, in the course of practice, many peculiar forms have been long established, and currently employed, in working it; such as straight lines, plain surfaces, square angles, and various mouldings used to soften the effect of abrupt terminations: all of which, originating in motives of mechanical convenience, and of simple ornament, had, in very early times, been appropriated to masonry, and considered as essential in every finished work of stone; so that, when the imitation of nature was introduced, these masonic forms still maintained their ground, and, being blended with the forms of nature, the two classes reciprocally modified each other.

“This combination of art with nature, of which we see the most perfect example in the Corinthian capital, produces what are called architectonic forms, in which the variety of nature, being subjected to the regularity of art, the work acquires that peculiar character which, in a natural object, we consider as offensive, under the name of *formality*; but which, in architecture, we admire as a beauty, under the name of *symmetry*: thus, we reprobate the formality of an avenue, and praise the symmetry of a colonnade.

“Such is the nature of architectonic imitation; a device which probably originated in accident, but to which architecture is indebted for its highest attainments.”

As the stone edifices of ancient Greece were constructed in imitation of a wooden fabric, composed of square beams laid at right angles on round posts or stems of trees, Sir James conceives that the Gothic fabrics with pointed arches have been executed in imitation of a rustic dwelling, constructed in the following manner: Suppose a set of round posts driven firmly into the ground in two opposite rows, the interval between the neighbouring posts in the same row being

equal to that between the rows, and each post being raised above the ground to a height equal to three of those intervals; then a set of long and flexible rods of willow being applied to each post, let them be thrust into the ground at its base, and bound to it by two tyings, one near the ground, and another at two-thirds of its height; the rods being left loose from this last point upwards, and free to be moved in any direction. Let three rods be connected with each outside corner post, and five with each of the others, and let their position be such as to cover the inside of the post, so that when seen from between the rows the lower part of each post shall be concealed from the view, and present the appearance of a bundle of rods (fig. 1.)

Things being thus disposed, the skeleton of a thatched roof may be formed by means of the loose ends of the rods. A rod from one of the posts being so bent as to meet a similar one from the post immediately opposite to it, in the middle of the space between them, let the two rods be made to cross each other, and let them be bound together at their crossing (fig. 2.), and we shall have the exact form of the Gothic arch. The same being done with each pair of opposite posts, and a set of pointed arches being formed, let them be connected together by means of a straight pole laid upon the forks of the crossing rods, and bound to each of them, as in fig. 3: then let a loose rod be brought from each of any two contiguous posts in the same row, so as to form a pointed arch, similar to that just described, and nearly of the same height. This being done with every two contiguous posts (fig. 4), and a new set of pointed arches being thus produced, standing opposite to each other in pairs, let each pair be bound by a horizontal pole lying on the opposite forks, and crossing the longitudinal pole described above.

“Two of the rods of each corner post, and three of those of each of the others, being thus disposed of, we have one of each corner post and two of each middle post still to employ, which is done as follows: A pair of these unoccupied rods being brought from any two posts which stand diagonally to each other, and made to meet in the middle, not as in the first case crossing in an angle, but side by side, forming a semicircle, and joined together after the manner of a hoop; and the same being done with every pair of diagonal posts (fig. 5.), the whole rods will have been employed.

“In this manner a frame would be constructed fit to support thatch or other covering; and such a one has probably been often used. It would seem, however, that, for the sake of strength, the number of rods has been increased in each cluster, by the introduction, between every two of them, of an additional rod, which rising with them to the roof, still continues its middle position, as they spread asunder, and meets the horizontal pole at an intermediate point. This is shown in fig. 6. which is drawn with its covering of thatch; and, from the imitation of a dwelling so constructed, we may easily trace the three leading characteristics of Gothic architecture, the pointed arch, the clustered column, and the branching roof, as exhibited in fig. 7.”

Upon the same principles Sir James Hall, with much ingenuity, accounts for the peculiar forms of the Gothic door, the Gothic window, and the pointed spire: but it is not our intention to supersede the necessity of having recourse to his memoir, but to excite the desire

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Plate V.

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Fig 1

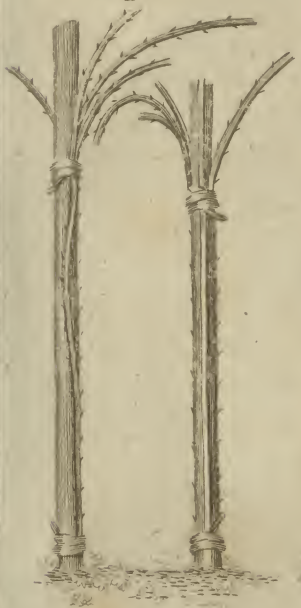


Fig 2.

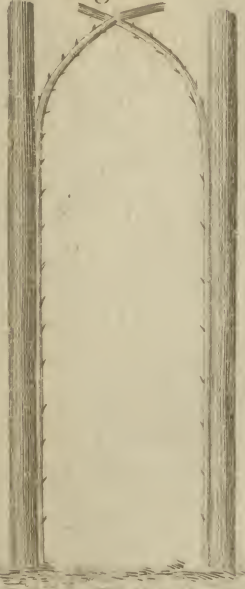


Fig 3



Fig 4.



Fig 7

Fig 6.

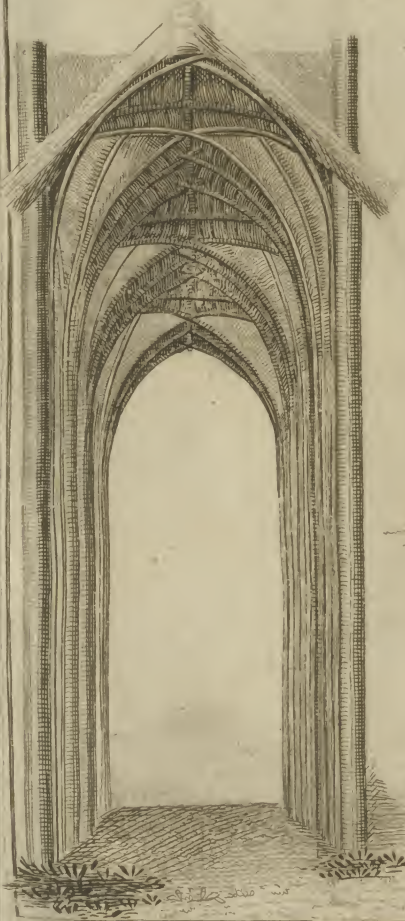
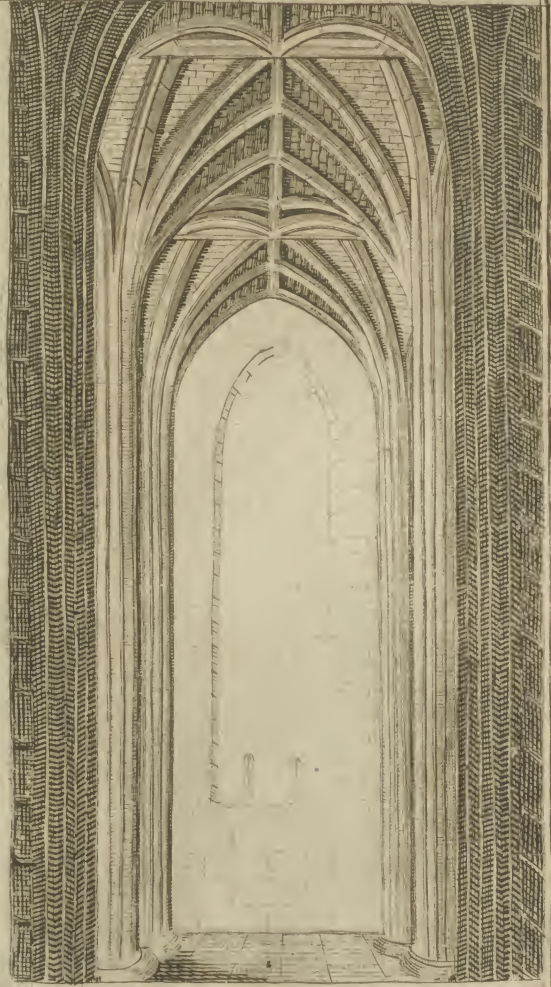


Fig 5.



Archite-
ture
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Arithmetic.

of our readers to peruse as well that paper as a larger work which he promises on the same subject, and in which we doubt not but they will find both entertainment and instruction. We shall conclude this article, therefore, with an experimental proof of the justness of his hypothesis.

In the greater part of our late attempts at Gothic architecture, it is allowed by every man of taste that we have failed. The failure is to be accounted for by the buildings having been constructed upon no consistent principle, applicable to every part of them, but upon a servile copying of ancient edifices, of which the structure was little understood by the copiers. Sir James Hall, however, by applying his theory to practice, has constructed a building in this style, which has far surpassed, he says, his own expectation, and has certainly gained the approbation of every man of taste and science by whom we have had occasion to hear it mentioned. "A set of posts of ash, about three inches in diameter, were placed in two rows, four feet asunder, and at the interval of four feet in the rows; then a number of slender and tapering willow rods, ten feet in length, were applied to the posts, and, in the manner which we have described, formed into a frame, which being covered with thatch, produced a very substantial roof, under which a person can walk with ease.

"This little structure exhibits, in miniature, all the characteristic features of the Gothic style. It is in the form of a cross, with a nave, a choir, and a north and south transept. The thatch, being so disposed on the frame as not to hide the rods of which it is composed, they represent accurately the pointed and semicircular arches, and all the other peculiarities of a groined roof."

ARCTUS, a name given by the Greeks to two constellations of the northern hemisphere, by the Latins called *URSA Major* and *Minor*, and by us the *Greater* and *Lesser BEAR*.

BINARY ARITHMETIC. See *BINARY Arithmetic*, Encycl.

Duodecimal ARITHMETIC, is that which proceeds from 12 to 12, or by a continual subdivision according to 12. This is greatly used by most artificers in calculating the quantity of their work; as bricklayers, carpenters, painters, tilers, &c.

Harmonical ARITHMETIC, is so much of the doctrine of numbers as relates to the making the comparisons, reductions, &c. of musical intervals.

ARITHMETIC of infinites, is the method of summing up a series of numbers, of which the number of terms is infinite. This method was first invented by Dr Wallis, as appears by his treatise on that subject; where he shows its uses in geometry, in finding the areas of superficies, the contents of solids, &c. But the method of fluxions, which is a kind of universal arithmetic of infinities, performs all these more easily, as well as a great many other things, which the former will not reach.

Logistical ARITHMETIC, a name sometimes employed for the arithmetic of sexagesimal fractions, used in astronomical computations. Shakerly, in his *Tabule Britannicæ*, has a table of logarithms adapted to sexagesimal fractions, which he calls *logistical logarithms*: and the expeditious arithmetic, obtained by means of them, he calls *logistical arithmetic*. The term *logistical arith-*

metic, however, or *logistics*, has been used by Vieta and others for the rules of computations in algebra.

Political ARITHMETIC. See *POLITICAL Arithmetic*, Encycl.

Sexagesimal ARITHMETIC. See *ARITHMETIC (Hist.)* Encycl.

Tetraëtic ARITHMETIC, is that in which only the four characters 0, 1, 2, 3, are used. A treatise of this kind of arithmetic is extant by Erhard or Echard Weigel. But both this and binary arithmetic are little better than curiosities, especially with regard to practice; as all numbers are much more compendiously and conveniently expressed by the common decuple scale.

Universal ARITHMETIC, is the name given by Newton to the science of algebra; of which he left at Cambridge an excellent treatise, being the text-book drawn up for the use of his lectures, while he was professor of mathematics in that university.

ARITHMETICAL COMPLEMENT, of a logarithm, is what the logarithm wants of 10.00000, &c. and the easiest way to find it is, beginning at the left hand, to subtract every figure from 9, and the last from 10.

ARTEDI (John), was born in the year 1705, in the province of Angermania, in Sweden. From nature he inherited an ardent passion for all branches of natural history, but he excelled most in that branch of it which is termed *ichthyology*. In 1724 he went to study at the university of Upsal, where some years afterwards he gained the friendship of the immortal Linnæus, who narrates the principal events of his life in the following animated terms.

"In 1728 (says Linnæus) I came from Lund to Upsal. I wished to devote myself to medicine. I inquired who, at that university, excelled most for his knowledge: every one named Artedi. I was impatient to see him. I found him pale, and in great distress for the loss of his father, with his thin hair neglected. He resembled the portrait of Ray the naturalist. His judgment was ripe, his thoughts profound, his manners simple, his virtues antique. The conversation turned upon stones, plants, animals. I was enchanted with his observations, equally ingenious and new; for at the very first he was not afraid to communicate them to me with the utmost frankness. I desired his friendship, he asked mine. From that moment we formed a friendship; which we cultivated with the greatest ardour for seven months at Upsal. I was his best friend, and I never had any who was more dear to me. How sweet was that intimacy! With what pleasure did we see it increase from day to day! The difference, even of our characters, was useful to us. His mind was more severe, more attentive; he observed more slowly, and with greater care. A noble emulation animated us. As I despaired of ever becoming as well instructed in chemistry as he, I abandoned it; he also ceased to study botany with the same ardour, to which I had devoted myself in a particular manner. We continued thus to study different branches of science; and when one of us excelled the other, he acknowledged him for his master. We disputed the palm in ichthyology; but soon I was forced to yield, and I abandoned that part of natural history to him, as well as the amphibia. I succeeded better than he in the knowledge of birds and insects,

Arithmetic
||
Artedi.

Artedi. infects, and he no longer tried to excel in these branches. We marched together as equals in lithology, and the history of quadrupeds. When one of us made an observation, he communicated it to the other: scarce a day passed in which one did not learn from the other some new and interesting particular. Thus emulation excited our industry, and mutual assistance aided our efforts. In spite of the distance of our lodgings, we saw each other every day. At last I set out for Lapland; he went to London. He bequeathed to me his manuscripts and his books.

"In 1735 I went to Leyden, where I found Artedi. I recounted my adventures; he communicated his to me. He was not rich, and therefore was unable to be at the expence of taking his degrees in physic. I recommended him to Seba, who engaged him to publish his work on fishes. Artedi went to join him at Amsterdam.

"Scarcely had I finished my *Fundamenta Botanica*. I communicated it to him; he let me see his *Philosophia Ichthyologica*. He proposed to finish as quickly as possible the work of Seba, and to put the last hand to it. He showed me all his manuscripts which I had not seen. I was pressed in point of time, and began to be impatient as being detained so long. Alas! if I had known this was the last time I should see him, how should I have prolonged it!

"Some days after, as he returned to sup with Seba, the night being dark, he fell into the canal. Nobody perceived it, and he perished. Thus died, by water,

this great ichthyologist, who had ever delighted in that element." **Artedi.**

Of the works of this eminent naturalist there have been two editions, of which the former was published by Linnæus in 1738, and the latter by Dr Walbaum of Lubeck, in the years 1788, 1789, and 1792. This edition, which is by much the most valuable, is in three volumes 4to; of which the first contains the history of the science of ichthyology, commencing several years before the Christian era, and coming down to the present times. The second presents to the reader the *Philosophia Ichthyologica* of Artedi, improved by Walbaum, who was benefited by the writings of Monro, Camper, Kætsfeuter, and others. Here also are added tables containing the system of fishes by Ray, Dale, Schæffer, Linnæus, Gowan, Scopola, Klein, and Gronovius. The third volume, which completes the collection of Artedi's works, contains the technical definitions of the science. After the generic and individual characters come the names and Latin phrases of Artedi; the synonyms of the best naturalists; the vulgar names in English, German, Swedish, Russian, Danish, Norwegian, Dutch, and Samoyed; the season and the countries where every kind is found, their varieties, their description, and observations. The modern discoveries, even to our own times, are added; so that in this part is collected the observations of Gronovius, Brunich, Penant, Forster, Klein, Bloch, Gmelin, Haffelquist, Broussonet, Leske, Buish, Linnæus, and other great examiners of nature.

A S T R O N O M Y

Is a science which has been cultivated from the earliest ages, and is conversant about the most sublime objects of inquiry which can employ the mind of man. It has accordingly been treated at great length in the *Encyclopædia Britannica*; but, in the opinion of some of the most judicious readers of that work, the compiler of the system which is there delivered has failed in his attempt to give a perspicuous and connected view of the science in its present state of improvement. This defect it is our duty to remedy. Our object, therefore, in this supplementary article, will be to bring into one point of view the physical science which may be derived from the consideration of the celestial motions; that is, to deduce from the general laws of those motions the inferences with respect to their supposed causes, which constitute the philosophy of the astronomer.

The causes of all phenomena are not only inferred from the phenomena, but are characterised by them; and we can form no notion of their nature but what we conceive as competent to the phenomena themselves. The astronomical phenomena are assumed to be the motions of the *bodies*, which we call the *sun*, the *planets*, the *comets*, &c. The notion which we express by the word *body* in the present case, is supposed to be the same with that which we form of other objects around us, to which we give the same name; such as stones, sticks, the bodies of animals, &c. Therefore the notion which we have of the causes of the celestial motions must be the same with that which we have of the causes of motion

in those more familiar bodies. All men seem to have agreed in giving the name **FORCES**, or **MOVING FORCES**, to the causes of those familiar motions. This is a figurative or metaphorical term. The true and original meaning of it is, the exertion which we are conscious of making when we ourselves put other bodies in motion. Force, when used without figure, always signifies the exertion of a living and acting thing. We are more interested in those productions of motion than in any other, and our recollections of them are more numerous. Hence it has happened that we use the same term to express the cause of bodily motion in general, and say that a magnet has force, that a spring has force, that a moving body has force.

Our own force is always exerted by the intervention of our own body; and we find that the same exertion by which we move a stone, enables us to move another man; therefore we conceive his body to resemble a stone in this respect, and that it also requires the exertion of force to put it in motion. But when we reflect on our employment of force for producing motion in a body, we find ourselves puzzled how to account for the motion of our own bodies. Here we perceive no intervening exertion but that of willing to do it; yet we find that we cannot move it as we please. We also find that a greater motion requires a greater exertion. It is therefore to this exertion that the reflecting man restrains the term *force*; and he acknowledges that every other use of it is metaphorical, and that it is a resemblance

I
Object of
this article.

2
Metaphor
cal use of
the term
force.

blance in the ultimate effect alone which disposes us to employ the term in such cases: but we find no great inconvenience in the want of another term.

We farther find, that our exertion is necessary, not only for producing motion where there was none before, but also for producing any change of motion; and accurate observation shews us, that the same force is required for changing a motion by any given quantity, as for producing that quantity where there was none before.

Lastly, we are conscious of exerting force when we resist the exerted force of another; and that an exertion, perfectly similar to this, will prevent some very familiar tendencies to motion in the bodies around us: thus an exertion is necessary for carrying a weight, that is, for preventing the fall of that weight.

All these resemblances between the effects of our forcible exertions and the changes of motion which accompany the meeting, and sometimes the mere vicinity of other bodies, justify us in the use of this figurative language. The resemblance is found to be the more perfect as we observe it with more care, and, in short, appears to be without exception. Bodies are therefore said to *act* on each other, to *resist* each other, to *resist* a change of motion, &c.

Therefore, wherever we observe a change of motion, we infer the existence and exertion of a changing force; and we infer the direction of that exertion from the direction of the change; and the quantity of the exertion, or intensity of the force, from the quantity of the change.

The study of the causes of the celestial motions is therefore hardly different from the study of the motions themselves; since the agency, the kind, and the degree of the moving force, are immediate inferences from the existence, the kind, and the quantity of the change of motion.

Our notion of a moving power is that of a power which produces motion, that is, a successive change of place. Continuation of the motion produced is therefore involved in the very notion of the production of motion; therefore the continued agency of the moving power, or of any power, is not necessary for the continuation of the motion. Motion is considered as a state or condition of the body; there is not any exertion of power therefore in the continuation of motion: But every change is indicative of a changing cause; and when the change is the same, in all its circumstances, the cause is necessarily conceived to be the same, or equal.

The condition of a body, in respect of motion, can differ from that of another equal body only in its direction and in its velocity. If the directions are the same, the difference of conditions can only be in the difference of velocity. One body has a determination, by which it would describe ten feet uniformly in a second, if nothing changed this determination; the other has a determination, by which it would describe twenty feet in a second. Each of these determinations are supposed to be the effects of forces acting similarly in every respect. Therefore these determinations are the only measures of these two forces; that is, moving forces are conceived by us as having the proportion of the velocities which they produce in a body by acting in a manner perfectly similar.

We can conceive a force acting equally or unequally. If we suppose it to act equally or uniformly, we suppose that in equal times it produces equal effects; that is, equal determinations, or equal changes of determination. We have no other notion of equality or uniformity of action. Therefore it must produce equal augmentations or diminutions of velocity in equal times; therefore it must produce an *uniformly* accelerated or retarded motion. Uniformly accelerated or retarded motion is, therefore, the mark of uniform or unvaried action. In such a motion, the changes of velocity are proportional to the times from the beginning of the action; and if the motion has begun from rest, the whole acquired velocities are proportional to the times from the beginning of the motion. In this case, the spaces described are as the squares of the times from the beginning of the motion; and thus we arrive at an ostensible mark of the unvaried action of a moving force, viz. spaces increasing in the duplicate ratio of the times: for space and time are all that we can immediately observe in any motion that is continually varying; the velocity or determination is only an inference, on the supposition that the motion continues unchanged for some time, or that all action ceases for some time.

This abstract reasoning is perfectly agreeable to every phenomenon that we can observe with distinctness. Thus we cannot, or at least we do not, conceive the weight of a body to vary its action during the fall. We consider this weight as the cause of the fall—as the moving force—and we conceive it to act uniformly. And, in fact, a body falling freely, describes spaces which are proportional, not to the times, but to the squares of the times, and the fall is a motion uniformly accelerated. In like manner, the motion of a body rising in the air, in opposition to gravity, is uniformly retarded.

This kind of motion also gives us a certain measure of the acquired velocity, although there is not, in fact, any space observed to be uniformly described during any time whatever. In this motion we know that the final determination, produced by the accumulated or continued action of the unvaried force, is such that the body would describe uniformly twice the space which it has described with the accelerated motion.

And it is by this method that we obtain the simplest measure of any moving force, and can compare it with another. If we observe that by the action of one force (known to be uniform by the spaces being proportional to the squares of the times) ten feet have been described in a second, and that by the uniform action of another force eighty feet are described in two seconds, we know that the last force is double of the first: for in the second motion, 80 feet were described in two seconds, and therefore 20 feet of this were described in the first second (because the motion is uniformly accelerated; and at the end of a second, the first body had a determination by which it would describe 20 feet uniformly in a second; and the second body had acquired a determination by which it would have described 40 feet uniformly in the next second, had not the moving force continued to act on it, and made it really describe 60 feet with an accelerated motion.

Because halves have the same proportions with the units of which they are the halves, it is plain that we may take the spaces, described in equal times with motions

3
Our notion
of a moving
power.

4
Measure of
moving
forces.

5
Accelerated motion
the mark of
unvaried
action;

6
And gives
a measure
of the ac-
quired ve-
locity.

tions uniformly accelerated, as measures of the forces which have produced those motions. The velocities generated are, however, the best measures.

7
Measure of the velocity produced by action not uniform.

When the actions of forces are not uniform, it is more difficult to learn what is the measure of the velocity produced by their accumulated action. But it can be determined with equal accuracy; that is, we can determine what is the velocity which *would have been produced* by the uniform action of the force during the same time, and therefore we obtain a measure of the force. Mathematicians are farther able to demonstrate, that if forces vary their continued action in any manner whatever, the proportion of the spaces described by two bodies in equal times approaches nearer and nearer to the proportion of the spaces which they would describe in those times by the uniform action of the forces, as the times themselves are smaller; and therefore whenever we can point out the ultimate ratio of the spaces described in equal times, these times being diminished without end, we obtain the ratio of the forces.

Motions may be changed, not only in quantity, by acceleration or retardation, but also in direction, by deflecting a body from its former direction. When a body, moving uniformly in the direction AB (fig. 1.), has its motion changed in the point B, and, instead of describing BC uniformly in the next moment with the former velocity, describes BD uniformly in that moment, it is plain that the motion BD will be the same, whether the body had begun to move in A, or in F, or in G, or in B, provided only that its determination to move, or its velocity, be the same in all those points. Complete the parallelogram BCDE. It is well known, that if one force act on the body which would make it describe BC, and another which would make it describe BE, the body will describe BD. Hence we learn, that when a body has the motion BC changed into the motion BD, it has been acted on in the point B by a force which would have caused a body at rest in B to describe BE. Thus we can discover the intensity and direction of the transverse force which produces any deflection from the former direction. In general, the force is that which would have produced in a body at rest that motion BE, which, when compounded with the former motion BC, produces the new motion BD.

8
Intensity and direction of deflecting forces.

These two principles, viz. 1st, that forces are proportional to the velocities which they produce in the same circumstances, and, 2d, the composition of motion or forces, will serve for all the physical investigations in astronomy. All the celestial motions are curvilinear, and therefore are instances of continual deflection, and of the continual action of transverse or deflecting forces. We must therefore endeavour to obtain a general measure of such continual deflecting forces.

9
Measure of these forces obtained.

Let two bodies A and a (fig. 2.) describe in the same time the arches AC, ac of two circles. They are deflected from the tangents AB, ab. Let us suppose that the direction of the deflecting forces is known to be that of the chords AE, ae of these circles. Let these be called the DEFLECTIVE CHORDS. Draw CB, cb parallel to AE, ae, and CD, cd parallel to AB, ab. Join AC, ac, CE, and ce. It is plain that the angle BAC is equal to the angle CEA in the alternate segment. Therefore ACD is also equal to it; and, because the angle CAD is common to the two triangles CAD and EAC, these two triangles are similar, and

AD : AC = AC : AE, and $AD = \frac{AC^2}{AE}$. For similar reasons $ad = \frac{ac^2}{ae}$. But AD and ad are respectively equal to BC and bc. Therefore $BC = \frac{AC^2}{AE}$,

and $bc = \frac{ac^2}{ae}$. Therefore $BC : bc = \frac{AC^2}{AE} : \frac{ac^2}{ae}$, or

$BC : bc = AC^2 \times ae : ac^2 \times AE$. But BC and bc being respectively equal to AD and ad, are equal to the spaces through which the deflecting forces would have impelled the bodies from a state of rest in the time of describing the arches AC, ac. Therefore, when these times are diminished without end, the *ultimate* ratio of AD and ad is the ratio of the forces which deflect the bodies in the points A and a. But it is evident that the ultimate ratio of AC to ac is the ratio of the velocity in the point A to the velocity in the point a; because these arches are supposed to be described in the same or equal times. Therefore the deflecting forces, by which bodies are made to describe arches of circles, are to each other as the squares of the velocities directly, and as the deflective chords of those circles inversely. This ratio may be expressed symbolically thus,

$$F : f = \frac{V^2}{C} : \frac{v^2}{c}; \text{ or thus, in a proportional equation, } f \doteq \frac{v^2}{c}.$$

It is easy to see that in this last formula *f* expresses directly the line *bc*, or the space through which the body is actually made to deviate from rectilinear motion in the time of describing the arch *ac*. It is a third proportional to *ae* the deflective chord, and *ac* the arch of the circumference described in a small moment of time. This is the measure afforded immediately by observation. We have observed the arch AC that is described, and know the direction and the length of AE from some circumstances of the case. The formula which comes to us, when treating this question by the help of

fluxions, is $f = \frac{2v^2}{c}$. This is perhaps a more proper expression of the physical fact; for it expresses twice the line *bc*, or the measure of the velocity which the deflecting force would have generated in the body by acting on it during the time of its describing the arch *ac*. But it is indifferent which measure we take, provided we always take the same measure. The first mathematicians, however, have committed mistakes by mixing them.

The planets, however, do not describe circles: but all the curves which can be described by the action of finite deflecting forces are of such a nature, that we can describe a circle through any point, having the same tangent, and the same curvature which the planetary curve has in that point, and which therefore ultimately coalesces with it. This being the case, it is plain that the planet, while passing through a point of the curve, and describing an indefinitely small arch of it, is in the same condition as if describing the coincident arch of the equicurve circle. Hence we obtain this most general proposition, that *the transverse force by which a planet is made to describe any curve, is directly as the square of its velocity, and inversely as the deflective chord of the equicurve circle.*

Farther: The velocity of a body in any point A (fig.

(fig. 2.) of the curve, is equal to that which the deflective force in that point would generate in the body by acting uniformly on it along AF, one-fourth part of the deflective cord AE of the equicurve circle. It is the same which the body would acquire at F, after a uniformly accelerated motion along AF.

For it is certain that there is some length AF, such that the velocity acquired at F is the same with the velocity in the point A of the curve. Draw FG parallel to the tangent, and join AG. Make the arch ACI = 2AF. Then, because the space described with a uniformly accelerated motion is one half of the space which would be uniformly described with the final velocity, the arch ACI would be uniformly described with the velocity which the body has at A in the time that AF is described with the uniformly accelerated motion; and the arch AB will be to the arch AI as the time of describing AB to that of describing AI; that is, as the time of falling through AD to that of falling through AF. But the motion along AF being uniformly accelerated, the spaces are as the squares of the times. Therefore AD is to AF as the square of the arch AC to the square of the arch AI. But AD is to AF as the square of the chord AC is to the square of the chord AG. Therefore the arch AC is to the chord AC as the arch AI is to the chord AG. But the arch and chord AC are ultimately in the ratio of equality. Therefore the chord AG is equal to the arch AI. Therefore AG is double of AF. But because the triangles FAG and GAE are similar, AF is to AG as AG to AE; and therefore AE is double of AG and quadruple of AF. Therefore the velocity at A in the curve is that which would be produced by the uniform impulse of the deflecting force along the fourth part of the deflective chord of the equicurve circle.

10
Two useful
affections of
curvilinear
motions.

These two affections or properties of curvilinear motions are of the most extensive use, and give an easier solution of most questions than we obtain by the more usual methods, and deserve to be kept in remembrance by such as engage much in the discussion of questions of this kind.

Thus the investigation of the forces which regulate the planetary motions is reduced to the task of discovering the velocity of the planet in the different points of its orbit, and the curvature in those points, and the position of the deflective chords.

11
Physical
science of
astronomy

The physical science of astronomy must consist in the discovery of the general laws which can be affirmed with respect to the exertion of those forces, whether with respect to their direction or the intensity of their action. If the mechanician can do more than this, and show that every motion that is observed is an immediate or remote consequence of those general laws, he will have completed the science, and explained every appearance.

12
Completed
by Newton
and

This has accordingly been done by Sir Isaac Newton and his followers. Sir Isaac Newton has discovered the general laws which regulate the exertions of those forces which produce the planetary motions, by reasoning from general phenomena which had been observed with a certain precision before his time; and has also shown that certain considerable deviations from the generality which he supposed to be perfect were necessary consequences of the very universality of the physical law, although the phenomenon was not so general as was at first imagined. He has gone farther, and has pointed out some other

minute deviations which must result from the physical law, but which the art of observation was not then sufficiently advanced to discover in the phenomena. This excited the efforts of men of science to improve the art of astronomical observation; and not only have the intimations of Newton been verified by modern observation, but other deviations have been discovered, and, in process of time, have also been shown to be consequences of the same general law of agency: And, at this present day, there is not a single anomaly of the planetary motions which has not been shown to be a modification of one general law which regulates the action; and therefore characterises the nature of that single force which actuates the whole system of the sun, and his attending planets and comets.

13
His follow-
ers.

It was a most fortunate circumstance that the constitution of the solar system was such that the deviations from the general law are not very considerable. The case might have been far otherwise, although the law, or nature of the planetary force, were the same, and the system had been equally harmonious and beautiful. Had two or three of the planets been vastly larger than they are, it would have been extremely difficult to discover any laws of their motion sufficiently general to have led to the suspicion or the discovery of the universal law of action, or the specific circumstance in the planetary force which distinguishes it from all others, and characterises its nature. But the three laws of the planetary motions discovered by Kepler were so nearly true, at least with respect to the primary planets, that the deviations could not be observed, and they were thought to be exact. It was on the supposition that they were exact, that Newton affirmed that they were only modifications of one law still more general, nay universal.

We shall follow in order the steps of this investigation.

Sir Isaac Newton took it for granted, that the sun and planets consisted of matter which resembled those bodies which we daily handle, at least in respect of their mobility; and that the forces which agitate them, considered merely as moving forces, but without considering or attending to their mode of operation, were to be inferred, both as to their direction and as to their intensity, from the changes of motion which were ascribed to their agency. He first endeavoured to discover the direction of that transverse force by which the planets are made to describe curve lines. Kepler's first law furnished him with ample means for this discovery. Kepler had discovered, that the right line joining the sun and any planet described areas proportional to the times. Newton demonstrated, that if a body was so carried round a fixed point situated in the plane of its motion, that the right line joining it with that point described areas proportional to the times, the force which deflected it from an uniform rectilinear motion was continually directed to that fixed point. This makes the 2d proposition of his immortal work *The Mathematical Principles of Natural Philosophy*, and it is given in the article ASTRONOMY of the *Encyclopædia Britannica*, § 260.

14
The steps
by which
they pro-
ceeded.

Hence Sir Isaac Newton inferred, that the primary planets were retained in their orbits by a force continually directed to the sun; and, because Kepler's law of motion was also observed by the secondary planets

in

in their revolutions round their respective primary planets, this inference was extended to them.

15
Centripetal force.

From the circumstance that the planetary deflecting forces in the different points of the orbit are always directed toward one point as to a centre, they have been called CENTRIPETAL FORCES.

16
Velocity of a planet in the different points of its orbit.

From this proposition may be deduced a corollary which establishes a general law of the motion of any planet in the different parts of its orbit, namely, that the velocity which a planet has in the different points of its path are inversely proportional to the perpendiculars drawn from the sun on the tangents to the orbit in those points respectively. For, let AB, *ab* (fig. 3.) be two arches (extremely small), described in equal times, these arches must be ultimately proportional to the velocities with which they are described. Let SP, S*p* be perpendicular to the tangents AP, *ap*. The triangles ASB, *aSb* are equal, because equal areas are described by the radii vectores SA, S*a*, in equal times: but in equal triangles, the bases AB, *ab*, are reciprocally as their heights SP, S*p*, or $AB : ab = Sp : SP$.

This corollary gives us another expression of the ratio of the centripetal forces in different points A and *a* of a curve. We saw by a former proposition, that the force at A (fig. 2.) is to the force at *a* as $AC^2 \times Ae$ to $a^2 \times AE$, which we may express thus: $F : f = V^2 \times c : v^2 \times C$. If we express the perpendiculars SP, S*p* (in fig. 3.) by the symbols P, *p*, we have $V^2 : v^2 = P^2 : p^2$, and therefore $F : f = p^2 \times c : P^2 \times C$. *The centripetal forces in different points of an orbit are in the ratio compounded of the inverse duplicate ratio of the perpendiculars drawn to the tangents in those points from the centre of forces, and the inverse ratio of the deflective chords of the equicurve circles.*

17
Law of action of the centripetal force,

We are now in a condition to determine the law of action of the centripetal force by which a planet is retained in its orbit round the sun, or the relation which subsists between the intensity of its action and the distance of the planet from the sun: for we know the elliptical figure of the orbit, and we can draw a tangent to it in any point, and a perpendicular from the sun to that tangent.

Kepler's second law or observation of the planetary motions was, that each primary planet described an ellipse, having the sun in one focus. It is easy to show, even without any knowledge of the geometrical properties of the ellipse, what is the proportion of the intensities of the deflecting force at the aphelion and perihelion (see fig. 4.) At those two points of the orbit, the motion of the planet is at right angles to the line joining it with the sun. Therefore, since the areas described in equal times are equal, the arches described in equal times must be inversely as the distances from the sun; or the velocities must be inversely as the distances from the sun. But the curvature in the aphelion and perihelion is the same; and therefore the diameters of the equicurve circles in those points are equal. But those diameters are, in this particular case, what we called the deflective chords. Therefore, calling the aphelion and perihelion distances D and *d*, the velocities in the aphelion and perihelion V and *v*, let the common deflective chord be C. Then we have $F : f = V^2 \times C : v^2 \times C = V^2 : v^2 = d^2 : D^2$. That is, the forces which deflect the planet in the aphelion and perihelion are inversely as the squares of the distances from the sun. A

person almost ignorant of mathematics may see the truth of this by looking into a table of natural versed sines. He will observe, that the versed sine of one degree is quadruple the versed sine of half a degree, and sixteen times the versed sine of a quarter of a degree; in short, that the versed sines of small arches are in the proportion of the squares of the arches. Now since the arches described in equal times are inversely as the distances, their versed sines are inversely as the squares of the distances. But these versed sines are the spaces through which the centripetal forces at the aphelion and perihelion deflect the planet from the tangent. Therefore, &c.

Thus we have found, that in the aphelion and perihelion the centripetal force acts with an intensity that is proportional to the squares of the distances inversely. As these are the extreme situations of a planet, and as the proportion of the aphelion and perihelion distances are considerably different in the different planets, and yet this law of action is observed in them all, it is reasonable to imagine that it holds true, not in those situations only, but in every intermediate situation. But a conjecture, however probable, is not sufficient, when we aim at accurate science, and it is necessary to examine whether this law of action is really observed in every point of the elliptical orbit.

For this purpose it is necessary to mention some geometrical properties of the ellipse. Therefore let ADBE (fig. 4.) be the elliptical orbit of a planet or comet, having the sun in the focus S. Let AB be the transverse axis, and DE the conjugate axis, and C the centre. Let P be any point of the ellipse. Draw PS through the focus. Draw the tangent PN, and SN from the focus, perpendicular to PN. Draw PQ perpendicular to PN, meeting the transverse axis in Q. Draw QO perpendicular to PN, meeting PS in O. Also draw QR perpendicular to PS. Bisection PO in T.

It is demonstrated in the treatises of conic sections, that PO is one half of the chord of the equicurve or osculating circle drawn through the point P. Therefore PO is one half of the deflective chord of the planetary orbit. It is also demonstrated, that PR is one half of the parameter or *latus rectum* of the transverse axis AB, or that it is the third proportional to AC and DC. Therefore PR or Dr is of the same constant magnitude, in whatever part of the circumference the point P is taken.

It is evident that the triangles NSP, RPQ, and QPO, are all similar, by reason of the parallels PN, QO, and the right angles SNP, PRQ, PQO. Therefore we have $PR : PQ = PQ : PO$. Therefore $PR : PO = PR^2 : PQ^2 = SN^2 : SP^2$. Therefore $PR \times SP^2 = PO \times SN^2$. But the *latus rectum* L is equal to twice PR, and the deflective chord C is equal to twice PO. Therefore $L \times SP^2 = C \times SN^2$. But we have seen, that when a curve is described by means of a centripetal force, so that areas are described proportional to the times, and therefore the velocities are reciprocally proportional to the perpendiculars drawn from the centre of forces to the tangents, the forces are inversely proportional to $C \times SN^2$. Therefore, in the elliptical motion of the planets, the forces are inversely proportional to $L \times SP^2$; and since L is a constant quantity, the centripetal forces are inversely proportional to SP^2 , or to the squares of the distances from the sun.

Thus

Thus it appears that, with respect to any individual planet, the centripetal force which continually deflects it from the tangent to its orbit diminishes in the inverse duplicate ratio of the distance from the sun. The same thing is observed to be very nearly true in the moon's motion round the earth, and in the motion of such satellites of Jupiter and Saturn as describe orbits which are sensibly elliptical. It is also observed in the motion of the comets, at least in that which appeared in 1682 and in 1759.

It was therefore very natural for Sir Isaac Newton to examine whether the like diminution of force obtained in the action of this force on different planets; that is, whether the deflection of the earth from the tangent of its orbit was to the simultaneous deflection of Jupiter as the square of Jupiter's distance from the sun to the square of the earth's distance. This was very probable, but by no means certain. Its probability is very great indeed, when we know that a comet moves so in its orbit that its deflections in equal times are inversely as the squares of its distances from the sun, and that the comet passes through the orbits of all the planets; and when at the same distance from the sun as any one of them, it suffers the same deflection with it. Newton therefore calculated the actual simultaneous deflections of the different planets, and found them agreeable to this law. But it was desirable to obtain a demonstration of this important proposition in general terms. This was supplied by Kepler's third general observation of the motions, viz. that *the squares of the periodic times of the different planets were proportional to the cubes of their mean distances from the sun.* The orbits of the planets are so nearly circular, that we may suppose them exactly so in the present question, without any remarkable error. In this case, then, the deflective chords are the diameters of the orbits (for DS is equal to AC), and are proportional to the distances, which are their halves. The centripetal forces, being proportional to

$\frac{v^3}{c}$, are proportional to $\frac{v^2}{d}$, when d is the radius of the orbit, or the mean distance from the sun. But the velocity in a circular orbit is as the circumference directly, and as the time of a revolution inversely. Therefore,

instead of v^2 , we may write $\frac{d^2}{t^2}$, and then the forces will be proportional to $\frac{d^2}{t^2 d}$, or to $\frac{d}{t^2}$; that is, directly as the distances, and inversely as the squares of the times of revolution. But, by Kepler's observation, t^2 is proportional to d^3 . Therefore the centripetal forces are proportional to $\frac{d}{d^3}$, or to $\frac{1}{d^2}$; that is, inversely as the squares of the mean distances from the sun.

But since the orbits of the planets are not accurate circles, this determination is but an approximation to the truth, and therefore insufficient for the foundation of so important a proposition; at any rate, it will not apply to the comets, whose orbits are very far from being circular. We must obtain a more accurate demonstration.

Therefore draw SD (fig. 4.) to the extremity of the conjugate axis, and bisect it in t . About S, with the radius SD, describe the circle DFG. Let D d , D s be equal small arches of the ellipse and the circle. Join

dS , sS . It is well known that DS is half of the chord of the equicurve circle at D, and therefore D t is one fourth part of it. It has been demonstrated, that the velocity in any point D of a curve, described by means of a deflecting force, is that which the force in that point would communicate to it by uniformly impelling it along the fourth part of the deflective chord, that is, along D t . But if a body revolved round S in a circle DFG, its velocity in that circle would be that which the deflecting force would communicate to it by uniformly impelling it along one-fourth of the diameter, that is, along D t . Therefore the planet, if projected in the direction D s , with the velocity which it has in the point D of the ellipse, would describe the circle DFG by the action of the centripetal force. Farther, it would describe it in the same time that it describes the ellipse; for because the velocities are equal, the areas DS d , DS s are described in the same time. But the bases D d , D s being equal, these areas are as their heights Sn (or CD), and SD (or CA). But because the diameter of the circle is equal to AB, the area of the whole ellipse is to the area of the circle as CD is to CA; that is, as the area DS d to the area DS s described in the same time. Therefore the elliptical and circular areas are similar portions of the ellipse and circle; and therefore the times of describing them are similar portions of the whole revolutions in the ellipse and in the circle. Therefore these revolutions are performed in equal times.

And thus it follows, that if all the planets and comets were projected, when at their mean distances from the sun, perpendicularly to the radii vectores, they would describe circles round the sun, and the squares of their periodic times would be proportional to the cubes of their mean distances from the sun, as Kepler has observed; and therefore the centripetal forces would be inversely as the squares of their distances from the sun.

They are not different forces therefore which retain the different planets in their respective orbits, but one force, acting by the same law upon them all. We may either conceive it as an attractive force, exerted by the sun, or as a tendency in each planet; nay, nothing hinders us from conceiving it as a force external, both to sun and planets, impelling them towards the sun. It may be the impulse of a stream of fluid moving continually towards the sun. Sir Isaac Newton did not concern himself with this question, but contented himself with the discovery of the law according to which its action was exerted. The steps of this investigation shewed him, that a body, projected in any direction whatever, and with any velocity whatever, and subjected to the action of a force directed to the sun, and inversely proportional to the square of the distance from the sun, will necessarily describe a conic section, having the sun in the focus. This will be a parabola, if the velocity of projection be that which the centripetal force in that place would communicate to the body by acting on it uniformly along a line equal to half its distance from the sun. If the velocity be greater than this, the path will be a hyperbola; if the velocity be less than this, the path will be an elliptical orbit, in which the body will revolve for ever round the sun.

The 3d Keplerean law is also observed in the revolutions of the satellites of Jupiter, Saturn, and the lately discovered

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observed in
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All the plan-
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one and the
same force.

discovered planet; and we must infer from it, that they are retained in their orbits round their respective primary planets, by forces whose intensity decreases according to the same law of the distances. Also the elliptical motion of the moon round the earth, shews that the force by which she is retained in her orbit varies in the same proportion of the distances. But when we compare the motion of a satellite of Jupiter with that of one of the satellites of the other two planets, we find that the proportion does not hold. We shall find that, at equal distances from Jupiter and Saturn, the force toward Jupiter is almost thrice as great as the force toward Saturn. We shall also find that the force toward Jupiter is three hundred times greater than the force which retains the moon in its elliptical orbit round the earth, when acting at the same distance.

Since a force directed to the sun, and inversely as the square of the distance, is thus found to pervade all the planetary orbits, it is highly improbable that it will not affect the secondary planets also. The moon accompanies the earth in its motion round the sun. It may appear sufficient for this purpose, that the moon be retained in its orbit by a force directed to the earth. Were the moon connected with the earth by a rope or chain, this would be true; for the earth could get no motion without dragging the moon along with it: but it is quite otherwise with bodies moving in free space, without any material connections. When a body that is moving uniformly in a straight line is accompanied by another which describes around it areas proportional to the times, the force which continually deflects this satellite is always directed to the moving central body. This is easily seen; for whatever be the mutual action of two bodies, and their relative motions in consequence of this action, if the same velocity be impressed at once on both bodies in the same direction, their mutual actions and relative motions will be the same as they would have been without this common impulse. Thus every thing is done in a ship that is sailing steadily in the same manner as if she were at rest. If therefore the moon be observed to describe areas round the earth, which are *precisely* proportional to the times, while the earth moves in an orbit round the sun, we must infer that the moon receives, in every instant, an impulse the same in every respect with what the earth receives at the same instant; or that the moon is acted on by a force parallel to the earth's distance from the sun, and proportional to the square of that distance inversely. Now this is very nearly true of the lunar motions; and we must infer that the moon is subjected to this solar action, or this tendency to the sun. The same must be affirmed of the satellites of the other planets.

But a force inversely proportional to the square of the earth's distance from the sun is not what the universality of the law requires: It must be inversely as the square of the moon's distance from the sun; and it must not be parallel to the earth's distance from the sun, but must be directed toward the sun; and therefore, in the quadratures, it must converge to the earth's *radius vector*. Therefore, since a force having the above mentioned conditions will allow the description of areas round the earth exactly proportional to the times, a force acting on the moon, inversely proportional to the square of her distance from the sun, and directed exactly to the sun, is incompatible with the accurate ellipti-

cal motion round the earth. At new moon, her tendency to the sun exceeds the earth's tendency to him, and this excess will diminish her tendency to the earth, and her motion will be less incurvated, so that she will retire a little from the earth. At full moon, the earth's tendency to the sun exceeds the moon's tendency to him, and the earth will separate a little from the moon, so that the relative orbit will again be less incurvated. In the quadratures, the impulse on the moon is indeed equal to that on the earth, but not parallel, and tends to make the moon approach the earth, and increase the curvature of her orbit. In other situations of the moon, this want of equality and parallelism of the forces acting on the earth and moon, must produce other disturbances of the regular elliptical motion.

Newton saw this at once; and, to his great delight, he saw that the great deviations from regular motion, which had been discovered by Ptolemy and Tycho Brahé, called the *Annual Equation*, the *Variation*, and the *Evection*, were such as most obviously resulted from the regular influence of the sun on the moon. The first deviation from the regular elliptical motion is occasioned by the increase of the sun's disturbing force as the earth approaches the perihelion; and it enlarges the lunar orbit, by diminishing the tendency to the earth, and increases the periodic time. The second arises from the *direction* of the disturbing force, by which it accelerates the moon's angular motion in the second and fourth quadrants of her orbit, and retards it in the first and third. The last affects the eccentricity of the orbit, by changing the ratio of the whole or compound tendency of the moon to the earth in her perigee and apogee. This success incited him to an accurate examination of the consequences of this influence. It is the boast of this discovery of the law of the planetary deflections, that all its effects may be calculated with the utmost precision. The part of the moon's deflection toward the sun, which is neither equal nor parallel to the simultaneous deflection of the earth, may be separated from the part which is equal and parallel to it, and it may be called the sun's disturbing force. Its proportion to the moon's deflection towards the earth may be accurately ascertained, and its inclination to the line of the moon's motion in every point of her orbit may be pointed out. This being done, the accumulated effect of this disturbing force after any given time, however variable, both in direction and intensity during this time, may be determined by the 39th and other propositions of the first book of the *Mathematical Principles of Natural Philosophy*. And thus may the moon's motion, when so disturbed, be determined and compared with her motion really observed.

All this has been done by Sir Isaac Newton with the most astonishing address and sagacity, *sua mathefi facem preferente*, partly in the *PRINCIPIA*, and partly in his *LUNÆ THEORIA*. This investigation, whether we consider the complete originality of the whole process, or the ingenuity of the method, or the sagacity in seeing and clearly discriminating the different circumstances of the question, or the wonderful fertility of resource, or the new and most refined mathematical principles and methods that he employed—must ever be considered as the most brilliant specimen of human invention and reasoning that ever was exhibited to the world.

In this investigation Newton not only determined the quantity,

22
The satellites of all the planets subjected to this solar action.

24
May be calculated with precision.

23
How the irregularity of the moon's motion

quantity, the period, and the changes of those inequalities, which had been so considerable and remarkable as to be observed by former astronomers, and this with an exactness far surpassing what could ever be attained by mere observation; but he also pointed out several other periodical inequalities, which were too small, and too much implicated with the rest, ever to be discovered or to be separated from them. We do not say that he completed the theory of the lunar motions; but he pointed out the methods of investigation, and he furnished all the means of prosecuting it, by giving the world the elements of a new species of mathematics, without which it would have been in vain to attempt it. Both this new mathematics, and the methods of applying it to such questions, have been assiduously studied and improved by the great mathematicians of this century; and the lunar theory has been carried to such a degree of perfection, that we can compute her place in the heavens for any past age without deviating above one minute of a degree from the actual observation.

There is one empirical equation of the moon's motion which the comparison of ancient and modern eclipses obliges the astronomers to employ, without being able to deduce it, like the rest, *à priori*, from the theory of an universal force inversely proportional to the square of the distance. It has therefore been considered as a stumbling block in the Newtonian philosophy. This is what is called *the secular equation of the moon's mean motion*. The mean motion is deduced from a comparison of distant observations. The time between them, being divided by the number of intervening revolutions, gives the average time of one revolution, or the mean lunar period. When the ancient Chaldean observations are compared with those of Hipparchus, we obtain a certain period; when those of Hipparchus are compared with some in the 9th century, we obtain a period somewhat shorter; when the last are compared with those of Tycho Brahé, we obtain one still shorter; and when Brahé's are compared with those of our day, we obtain the shortest period of all—and thus the moon's mean motion appears to accelerate continually; and the accelerations appear to be in the duplicate ratio of the times. The acceleration for the century which ended in 1700 is about 9 seconds of a degree; that is to say, the whole motion of the moon during the 17th century must be increased 9 seconds, in order to obtain its motion during the 18th; and as much must be taken from it, or added to the computed longitude, to obtain its motion during the 16th; and the double of this must be taken from the motion during the 16th, to obtain its motion during the 15th, &c. Or it will be sufficient to calculate the moon's mean longitude for any time past or to come by the secular motion which obtains in the present century, and then to add to this longitude the product of 9 seconds, multiplied by the square of the number of centuries which intervene. Thus having found the mean longitude for the year 1200, add 9 seconds, multiplied by 36, for six centuries. By this method we shall make our calculation agree with the most ancient and all intermediate observations. If we neglect this correction, we shall differ more than a degree from the Chaldean observations of the moon's place in the heavens.

The mathematicians having succeeded so completely in deducing all the observed inequalities of the planeta-

ry motions, from the single principle, that the deflecting forces diminished in the inverse duplicate ratio of the distances, were fretted by this exception, the reality of which they could not contest. Many opinions were formed about its cause. Some have attempted to deduce it from the action of the planets on the moon; others have deduced it from the oblate form of the earth, and the translation of the ocean by the tides; others have supposed it owing to the resistance of the ether in the celestial spaces; and others have imagined that the action of the deflecting force requires time for its propagation to a distance: But their deductions have been proved unsatisfactory, and have by no means the precision and evidence that have been attained in the other questions of physical astronomy. At last M. de la Place, of the Royal Academy of Sciences at Paris, has happily succeeded, and deduced the secular equation of the moon from the Newtonian law of planetary deflection. It is produced in the following manner:

Suppose the moon revolving round the earth undisturbed by any deflection toward the sun, and that the time of her revolution is exactly ascertained. Now let the influence of the sun be added. This diminishes her tendency to the earth in opposition and conjunction, and increases it in the quadratures; but the diminutions exceed the augmentations both in quantity and duration; and the excess is equivalent to $\frac{1}{177}$ th of her tendency to the earth. Therefore this diminished tendency cannot retain the moon in the same orbit; she must retire farther from the earth, and describe an orbit which is less incurvated by $\frac{1}{177}$ th part; and she must employ a longer time in a revolution. The period therefore which we observe, is not that which would have obtained had the moon been influenced by the earth alone. We should not have known that her natural period was increased, had the disturbing influence of the sun remained unchanged; but this varies in the inverse triplicate ratio of the earth's distance from the sun, and is therefore greater in our winter, when the earth is nearer to the sun. This is the source of the annual equation, by which the lunar period in January is made to exceed that in July nearly 24 minutes. The angular velocity of the moon is diminished in general $\frac{1}{177}$, and this numerical coefficient varies in the inverse ratio of the cube of the earth's distance from the sun. If we expand this inverse cube of the earth's distance into a series arranged according to the sines and cosines of the earth's mean motion, making the earth's mean distance unity, we shall find that the series contains a term equal to $\frac{1}{2}$ of the square of the eccentricity of the earth's orbit. Therefore the expression of the diminution of the moon's angular velocity contains a term equal to $\frac{1}{177}$ of this velocity, multiplied by $\frac{1}{2}$ of the square of the earth's eccentricity; or equal to the product of the square of the eccentricity, multiplied by the moon's angular velocity, and divided by 119,33 ($\frac{1}{3}$ of 179). Did this eccentricity remain constant, this product would also be constant, and would still be confounded with the general diminution, making a constant part of it: but the eccentricity of the earth's orbit is known to diminish, and its diminution is the result of the universality of the Newtonian law of the planetary deflections. Although this diminution is exceedingly small, its effect on the lunar motion becomes sensible by accumulation in the course of ages. The eccentricity diminishing, the dimi-

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Deduced from the Newtonian law of planetary deflection.

25
The secular equation of the moon's mean distance

nution of the moon's angular motion must also diminish, that is, the angular motion must increase.

During the 18th century, the square of the earth's eccentricity has diminished 0,0000015325, the mean distance from the sun being = 1. This has increased the angular motion of the moon in that time 0,0000001285. As this augmentation is gradual, we must multiply the angular motion during the century by the half of this quantity, in order to obtain its accumulated effect. This will be found to be 9" very nearly, which exceeds that deduced, from a most careful comparison of the motion of the last two centuries, only by a fraction of a second!

As long as the diminution of the square of the eccentricity of the earth's orbit can be supposed proportional to the time, this effect will be as the squares of the times. When this theory is compared with observations, the coincidence is wonderful indeed. The effect on the moon's motion is periodical, as the change of the solar eccentricity is, and its period includes millions of years. Its effect on the moon's longitude will amount to several degrees before the secular acceleration change to a retardation.

Those who are not familiar with the disquisitions of modern analysis, may conceive this question in the following manner.

Let the length of a lunar period be computed for the earth's distance from the sun for every day of the year. Add them into one sum, and divide this by their number, the quotient will be the mean lunar period. This will be found to be greater than the arithmetical medium between the greatest and the least. Then suppose the eccentricity of the earth's orbit to be greater, and make the same computation. The average period will be found still greater, while the medium between the greatest and least periods will hardly differ from the former. Something very like this may be observed without any calculation, in a case very similar. The angular velocity of the sun is inversely as the square of his distance. Look into the solar tables, and the greatest diurnal motion will be found 3673", and the least 3433". The mean of these is 3553", but the medium of the whole is 3548". Now make a similar observation in tables of the motion of the planet Mars, whose eccentricity is much greater. We shall find that the medium between the greatest and least exceeds the true medium of all in a much greater proportion.

Thus has the patient and assiduous cultivation of the Newtonian discoveries explained every phenomenon, and enabled us to foresee changes in them which no examination of the past appearances, unassisted by this theory, could have pointed out, and which must have exceedingly embarrassed future astronomers. This great but simple law of deflection represents every phenomenon of the system in the most minute circumstances. Far from fearing that future experience may overturn this law, we may rest assured that it will only confirm it more and more; and we may confide in its most remote consequences as if they were actually observed.

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Certain: ty
and utility
of this law.

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Reciprocal
deflection
of the earth
and moon,
and of the
sun and pla-
nets,

It is discovered by observation, that the deflection of the moon to the earth, and of the planets to the sun, are accompanied by an equal and opposite deflection of the earth to the moon, and of the sun to the planets. The tendency of the earth to the moon is plainly indicated by the rise of the waters of the ocean under the

moon, and on the opposite side of the earth. Sir Isaac Newton tried what should be the result of a tendency of the water to the moon. His investigation of this question was very similar to that in his lunar theory. We may conceive the moon to be one of many millions of particles of a fluid, occupying a globe as big as the lunar orbit. Each will feel a similar disturbing force, which will diminish its tendency to the earth in the neighbourhood of the place of conjunction and opposition, and will increase it in the neighbourhood of the quadratures. They cannot therefore remain in equilibrium in their spherical form; they must sink in the quadratures, and rise in the conjunction and opposition, till their greater height compensates for the diminished weight of each particle. In like manner, the waters of the ocean must sink on those parts of the earth where the moon is seen in the horizon, and must rise in those which have the moon in the zenith or nadir. All these effects are not only to be seen in general, but they may all be calculated, and the very form pointed out which the surface of the ocean must assume; and thus a tendency of every particle of the ocean to the moon, inversely proportional to the square of its distance from it, gives us a theory of the ebbing and flowing of the sea. This is delivered in sufficient detail in the article TIDE of the Encyclopædia Britannica, and therefore need not be insisted on in this place. The same inference must be drawn from the precession of the equinoxes produced by the action of the moon on the protuberant matter of our equatorial regions. See PRECESSION in the *Encycl.*

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Proved by
the ebbing
and flow-
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sea,

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And by d
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of the sun
place in t
heavens.

But the mutual tendency of the earth and moon is clearly seen in a phenomenon that is much more simple. If we compute the sun's place in the heavens, on the supposition that the earth describes areas proportional to the times, we shall find it to agree with observation at every new and full moon: But at the first quarter the sun will be observed about 9 seconds too much advanced to the eastward; and at the last quarter he will be as much to the westward of his calculated place. In all intermediate positions, the deviation of the observed from the computed place of the sun will be 9 seconds, multiplied by the sine of the moon's distance from conjunction or opposition. In short, the appearances will be the same as if it were not the earth which described areas proportional to the times round the sun, but that a point, lying between the earth and moon, and very near the earth's surface, were describing the ellipse round the sun, while the earth and moon revolve round this point in the course of a lunation, having the point always in the line between them, in the same manner as if they were on the extremities of a rod which turns round this point, while the point itself revolves round the sun.

This then is the fact with respect to the motions; and the earth in a month describes an orbit round this common centre of the earth and moon. It cannot do this unless it be continually deflected from the tangent to this orbit; therefore it is continually deflected toward the moon: and the momentum of this deflection, that is, its quantity of motion, is the same with that of the moon's deflection, because their distances from the common centre are as their quantities of matter inversely.

Appearances perfectly similar to these oblige us to affirm

affirm that the sun is continually deflected toward the planets. Astronomical instruments, and the art of observing, have been prodigiously improved since Sir Isaac Newton's time; and the most scrupulous attention has been paid to the sun's motion, because it is to his place in the universe that continual reference is made in computing the place of all the planets. He is supposed at rest in the common focus of all their orbits; and the *observed* distance of a planet from the sun is always considered as the *radius vector*. If this be not the case, the orbital motions contained in our tables are not the absolute motions of the planets, nor the deflections from the tangents the real deflections from absolute rectilinear motion; and therefore the forces are not such as we infer from those mistaken deflections. Accordingly Sir Isaac Newton, induced by certain metaphysical considerations, assumed it as a law of motion, that every action of a body A on another body B, is accompanied by an equal and contrary action of B on A. We do not see the propriety of this assertion as a metaphysical axiom. It is perfectly conceivable that a piece of iron will always approach a magnet when in its neighbourhood; but we do not see that this obliges us to assert, that *therefore* the magnet will also approach the iron. Those who explain the phenomena of magnetism by the impulse of a fluid, must certainly grant that there is no metaphysical necessity for another stream of fluid impelling the magnet toward the iron. And accordingly this, and the similar reciprocity in the phenomena of electricity, have *always* been considered as deductions of experimental philosophy; yet we observe the same reciprocity in all the actions of sublunary bodies; and Newton's third law of motion is received as true, and admitted as a principle of reasoning. But we apprehend that it was hasty in this great philosopher, and unlike his scrupulous caution, to extend it to the planetary motions. He did, however, extend it, and asserted, that as each planet was deflected toward the sun, the sun was equally (in respect of momentum) deflected toward each planet, and that his real motion was the composition of all those simultaneous deflections. He asserted that there was a certain point round which the sun and his attending planets revolved; and that the orbit of a planet, which our measurements determined by continual reference to the sun as to a fixed body, was not the true orbit, but consisted of the contemporaneous orbits of that planet and of the sun round this fixed point. Any little sector of the apparent orbit was greater than the corresponding sector of the planet's true orbit in absolute space, and the apparent motion was compounded of the true motion of the planet, and the opposite to the true motion of the sun. After a most ingenious and refined investigation, he shewed that, notwithstanding this great difference of the Keplerian laws from the truth, the inference, with respect to the law of planetary deflection, is just, and that not only the apparent deflections are in the inverse duplicate ratio of the distances from the sun, but that the real deflections vary in the same ratio of the distances from the fixed point, and also from the sun; for he shewed that the distances from the sun were in a constant ratio to the distances from this point. He shewed also that the same forces which produced the contemporaneous revolution of a planet and the sun round the centre of the system, would produce a revolution of

the planet in a similar orbit round the sun (supposed to be held fast in his place) at the same distance which really obtains between them, with this sole difference, that the periodic time will be longer, in the subduplicate ratio of the quantity of matter in the sun to the quantity of matter of the sun and planet together. Areas will be described proportional to the times, and the orbit will be elliptical; but the ratio of the squares of the periodic times will not be the same with the ratio of the cubes of the distances, unless all the planets are equal.

Thus was the attention of astronomers directed to a number of *apparent* irregularities in the motion of the earth, which must result from this derangement of the sun, which they had imagined to remain steadfast in his place. They were told what to expect, and on what positions of the planets the kind and quantity of every irregularity depended. This was a most inviting field of observation to a curious speculatist; but it required the nicest and most expensive instruments, and an uninterrupted series of long continued observations, sufficient to occupy the whole of a man's time. Fortunately the accurate determination of the solar and lunar motions were of the utmost importance, nay, indispensably necessary for solving the famous problem of the longitude of a ship at sea: and thus the demands of commercial Europe came in aid of philosophical curiosity, and occasioned the erection of observatories, first at Greenwich, and soon after at Paris and other places, with establishments for astronomers, who should carefully watch the motions of the sun and moon, not neglecting the other planets.

The fortunate result of all this solicitude has been the complete establishment of the Newtonian conjecture (for we must still think it), and the verification of Newton's assertion, that action was accompanied; through the whole solar system, by an equal and contrary reaction. All the inequalities of the solar motion predicted by Newton have been observed, although they are frequently so complicated that they could never have been detected, had not the Newtonian theory directed us when to find any of them pretty clear of complication, and how to ascertain the accumulated result of them all in any state of combination.

But in the course of this attention to the motions of the sun and moon, the planets came in for a share, and considerable deviations were found, from the supposition that all their deflections were directed to the sun, and were in the inverse duplicate ratio of their distances. The nice observation shewed, that the period of Jupiter was somewhat shorter than Kepler's law required.

A slight reflection shewed that this was no inconsistency; because the common centre of the conjoined orbits of the sun and Jupiter was sensibly distant from the centre of the sun, namely, about the 1100th part of the *radius vector*; and therefore the real deflection was about a 2200th part less than was supposed. It was now plain that the distances to which the Keplerian law must be applied, are the distances, not from the sun, but from the fixed point round which the sun and planets revolve. This difference was too small to be observed in Kepler's time; but the seeming error is only a confirmation of the Newtonian philosophy.

But there are other irregularities which cannot be explained in this manner. The planetary orbits change

31
Observations on the third law of motion.

32
Newton's extension of that law

33
Confirmed by observation.

their position; their aphelia advance, their nodes recede, their inclination to each other vary. The mean motions of Saturn and Jupiter are subject to considerable changes, which are periodical.

34
Deflection
of the pla-
nets to-
wards each
other.

Sir Isaac Newton had no sooner discovered the universality and reciprocity of the deflections of the planets and the sun, than he also suspected that they were continually deflected towards each other. He immediately obtained a general notion of what should be the more general results of such a mutual action. They may be conceived in this way.

Plate VI.

Let S (fig. 5.) represent the sun, E the earth, and I Jupiter, describing concentric orbits round the centre of the system. Make $IS : EA = EI^2 : SI^2$. Then, if IS be taken to represent the deflection of the sun toward Jupiter, EA will represent the deflection of the Earth to Jupiter. Draw EB equal and parallel to SI, and complete the parallelogram EBAD. ED will represent the disturbing force of Jupiter. It may be resolved into EF, perpendicular to ES, and EG in the direction of SE. By the first of these the earth's angular motion round the sun is affected, and by the second its deflection toward him is diminished or increased.

35
General re-
sult of such
mutual ac-
tion.

In consequence of this first part of the disturbing force, the angular motion is increased, while the earth approaches from quadrature to conjunction with Jupiter (which is the case represented in the figure), and is diminished from the time that Jupiter is in opposition till the earth is again in quadrature, westward of his opposition. The earth is then accelerated till Jupiter is in conjunction with the sun; after which it is retarded till the earth is again in quadrature.

The earth's tendency to the sun is diminished while Jupiter is in the neighbourhood of his opposition or conjunction, and increased while he is in the neighbourhood of his stationary positions. Jupiter being about 1000 times less than the sun, and 5 times more remote, IS must be considered as representing $\frac{1}{5000}$ th of the earth's deflection to the sun, and the forces ED and EG are to be measured on this scale.

In consequence of this change in the earth's tendency to the sun, the aphelion sometimes advances by the diminution, and sometimes retreats by the augmentation. It advances when Jupiter chances to be in opposition when the earth is in its aphelion; because this diminution of its deflection towards the sun makes it later before its path is brought from forming an obtuse angle with the *radius vector*, to form a right angle with it. Because the earth's tendency to the sun is, on the whole, more diminished by the disturbing force of Jupiter than it is increased, the aphelion of the earth's orbit advances on the whole.

In like manner the aphelia of the inferior planets advance by the disturbing forces of the superior: but the aphelion of a superior planet retreats; for these reasons, and because Jupiter and Saturn are larger and more powerful than the inferior planets, the aphelia of them all advance while that of Saturn retreats.

In consequence of the same disturbing forces, the node of the disturbed planet retreats on the orbit of the disturbing planet; therefore they all retreat on the ecliptic, except that of Jupiter, which advances by retreating on the orbit of Saturn, from which it suffers the greatest disturbance. This is owing to the particular position of the nodes and the inclinations of the orbits.

The inclination of a planetary orbit increases while the planet approaches the node, and diminishes while the planet retires from it.

M. de la Place has completed this deduction of the planetary inequalities, by explaining a peculiarity in the motions of Jupiter and Saturn, which has long employed the attention of astronomers. The accelerations and retardations of the planetary motions depend, as has been shewn, on their configurations, or the relative quarters of the heavens in which they are. Those of Mercury, Venus, the Earth, and Mars, arising from their mutual deflections; and their more remarkable deflections to the great planets Jupiter and Saturn, nearly compensate each other, and no traces of them remain after a few revolutions: but the positions of the aphelia of Saturn and Jupiter are such, that the retardations of Saturn sensibly exceed the accelerations, and the anomalistic period of Saturn increases almost a day every century: on the contrary, that of Jupiter diminishes. M. de la Place shews, that this proceeds from the position of the aphelia, and the almost perfect commensurability of their revolutions; five revolutions of Jupiter making 21,675 days, while two revolutions of Saturn make 21,538, differing only 137 days.

36
A peculiar-
ity ex-
plained in
the motion
of Jupiter
and Saturn.

Supposing this relation to be exact, the theory shews that the mutual action of these planets must produce mutual accelerations and retardations of their mean motions, and ascertains the periods and limits of the secular equations thence arising. These periods include several centuries. Again, because this relation is not precise, but the odd days nearly divide the periods already found, there must arise an equation of this secular equation, of which the period is immensely longer, and the maximum very minute. He shews that this retardation of Saturn is now at its maximum, and is diminishing again, and will, in the course of years, change to an acceleration.

This investigation of the small inequalities is the most intricate problem in mechanical philosophy, and has been completed only by very slow degrees, by the arduous efforts of the greatest mathematicians, of whom M. de la Grange is the most eminent. Some of his general results are very remarkable.

He demonstrates, that since the planets move in one direction, in orbits nearly circular, no mutual disturbances make any permanent change in the mean distances and mean periods of the planets, and that the periodic changes are confined within very narrow limits. The orbits can never deviate sensibly from circles. None of them ever has been or will be a comet moving in a very eccentric orbit. The ecliptic will never coincide with the equator, nor change its inclination above two degrees. In short, the solar planetary system oscillates, as it were, round a medium state, from which it never swerves very far.

37
Oscillati-
on of the pl-
anetary sy-
stem.

This theory of the planetary inequalities, founded on the universal law of mutual deflection, has given to our tables a precision, and a coincidence with observation, that surpasses all expectation, and insures the legitimacy of the theory. The inequalities are most sensible in the motions of Jupiter and Saturn; and these present themselves in such a complicated state, and their periods are so long, that ages were necessary for discovering them by mere observation. In this respect, therefore, the theory has outstripped the observations on which it is founded.

38
Authenti-
city of the
Indian a-
stronomy.

founded. It is very remarkable, that the periods which the Indians assign to these two planets, and which appeared so inaccurate that they hurt the credit of the science of those ancient astronomers, are now found precisely such as must have obtained about three thousand years before the Christian era; and thus they give an authenticity to that ancient astronomy. The periods which any nation of astronomers assign to those two planets would afford no contemptible mean for determining the age in which it was observed.

The following circumstance is remarkable: Suppose Jupiter and Saturn in conjunction in the first degree of Aries; twenty years after, it will happen in Sagittarius; and after another twenty years, it will happen in Leo. It will continue in these three signs for 200 years. In the next 200 it will happen in Taurus, Capricornus, and Virgo; in the next 200 years, it will happen in Gemini, Aquarius, and Libra; and in the next 200 years, it will happen in Cancer, Pisces, and Scorpio: then all begins again in Aries. It is highly probable that these remarkable periods of the oppositions of Jupiter and Saturn, progressive for 40 years, and oscillating during 160 more, occasioned the astrological division of the heavens into the four *trigons*, of fire, air, earth, and water. These relations of the signs, which compose a trigon, point out the repetitions of the chief irregularities of the solar system.

39
Origin of
the astrolo-
gical divi-
sion of the
heavens.

M. de la Place observes (in 1796), that the last discovered planet gives evident marks of the action of the rest; and that when these are computed and taken into the account of its bygone motions, they put it beyond doubt that it was seen by Flamsteed in 1690, by Mayer in 1756, and by Monnier in 1769.

40
Action of
the comets.

We have hitherto overlooked the comets in our account of the mutual disturbances of the solar system. Their number is very great, and they go to all quarters of the universe: but we may conclude, from the wonderful regularity of the planetary motions, when all their own mutual actions are taken into account, that the quantity of matter in the comets is very inconsiderable. They remain but a short time in the neighbourhood of the planets, and they pass them with great rapidity. Some of them have come very near to Jupiter, but left no trace of their action in the motions of his satellites. They doubtless contribute, in general, to make the apsidal of the planetary orbits advance.

41
They are
affected by
the planets.

On the other hand, the comets may be considerably affected by the planets. The very important phenomenon of the return of the comet of 1682, which was to decide whether they were revolving planets describing ellipses, or bodies which came but once into the planetary regions, and then retired for ever, caused the astronomers to consider this matter with great care. Halley had shewn, in a rough way, that this comet must have been considerably affected by Jupiter. Their motion near the aphelion must be so very slow; that a very small change of velocity or direction, while in the planetary regions, must considerably affect their periods. Halley thought that the action of Jupiter might change it half a year. Mr Clairaut, by considering the disturbing forces of Jupiter and Saturn through the whole revolution, shewed that the period then running would exceed the former nearly two years (618 days), and assigned the middle of April 1759 for the time of its perihelion. It really passed its perihelion on the 12th of March. This

was a wonderful precision, when we reflect that the comet had been seen but a very few days in its former apparitions.

A comet observed by Mr Prosperin and others in 1771 has greatly puzzled the astronomers. Its motions appear to have been extremely irregular, and it certainly came so near Jupiter, that his momentary influence was at least equal to the sun's. It has not been recognised since that time, although there is a great probability that it is continually among the planets.

It is by no means impossible, nor highly improbable, that in the course of ages, a comet may actually meet one of the planets. The effect of such a concourse must be dreadful; a change of the axis of diurnal rotation must result from it, and the sea must desert its former bed and overflow the new equatorial regions. The shock and the deluge must destroy all the works of man, and most of the race. The remainder, reduced to misery, must long struggle for existence, and all remembrance of former arts and events must be lost, and every thing must be invented anew. There are not wanting traces of such devastations in this globe: strata and things are now found on mountain tops which were certainly at the bottom of the ocean in former times; remains of tropical animals and plants are now dug up in the circumpolar regions. *Tempora mutantur, et nos mutantur in illis.*

42
Conse-
quence of s
comet and
planet
meeting.

It is plain, that when we know the direction and the intensity of the disturbing force, we can tell what will be the accumulated effect of its action for any time. The direction is easily determined by means of the distance: but how shall we determine the intensity? Since we see that the whole waters of the ocean are deflected toward the moon, and have such probable evidence that planetary deflection is mutual; it follows that the moon is deflected towards every drop of water, and that all the matter in one body is deflected towards all the matter in another body; and therefore that the deflection towards the sun or a planet is greater or less in proportion to its quantity of matter. Newton indeed thought it unreasonable to suppose that a planet was deflected to the centre of the sun, which had no distinguishing physical property; and thought it more probable that the deflection of a planet to the sun was the accumulated deflection of every particle in the planet to every particle in the sun. But he was too scrupulous to take this for granted. He therefore endeavoured to discover what would be the sensible deflection of one sphere to another, when each consisted of matter, every particle of which was deflected to every particle of the other with an intensity inversely proportional to the square of the distance from it. By help of a most beautiful and simple process, he discovered, that the tendency of a particle of matter to a spherical surface, shell, or solid, of uniform density at equal distances from the centre, was the same as if all the particles in the surface, shell, or solid, were united in its centre: hence it legitimately followed, that the mutual tendency of spherical surfaces, shells, or solids, was proportional to the quantities of matter in the attracting body, and inversely as the square of the distance of their centres; and thus the law of attraction, competent to every particle of planetary matter, was the same with that which was observed among spherical bodies consisting of such matter. And it is remarkable, that the inverse duplicate ratio

43
Tendency
of spherical
bodies to-
wards each
other di-
rectly as the
quantity of
matter, and
inversely as
the square
of the dis-
tance of
their cen-
tres.

ratio

tion of the distances is the only law that will hold, both with respect to single particles and to globes composed of such particles. He also demonstrated, that a particle placed within a sphere was not affected by all the shell, which was more distant than itself from the centre, being equally attracted on every side, and that it tended toward the centre of a homogenous sphere, on the surface of which it was placed, with a force proportional to its distance from the centre.

Newton saw a case in which it was possible to discover whether the tendency of the matter of which the planets consisted was directed to a mathematical centre void of any physical properties, or whether it was the result of its united tendency to all the matter of the planet. He demonstrated that if the earth consisted of matter which tended to the centre, it behoved it to assume the form of an elliptical spheroid, in consequence of the centrifugal force arising from its diurnal motion, and that the polar axis must be to its equatorial diameter as 577 to 578; but if every particle tends to every other particle in the inverse duplicate ratio of the distance from it, the form must still be elliptical, but more protuberant, and the polar axis must be to the equatorial diameter as 230 to 231. Then only will a column of water from the pole to the centre balance a column from the equator to the centre. He also shewed what should be the vibrations of pendulums in different latitudes, on both suppositions. Mathematicians were eager therefore to make those experiments on pendulums, and to determine the figure of the earth by the measurement of degrees of the meridian in different latitudes. The result of their endeavours has been decidedly in favour of the mutual tendency of all matter. This has been farther confirmed by the observations of the mathematicians who measured the degrees of the meridian in Peru, and by Dr Maskelyne in Britain, who found that a pendulum suspended in the neighbourhood of a great and solid mountain, sensibly deviated from the true vertical, and was deflected toward the mountain.

44
Proportional quantity of matter in the sun and planets determined.

From a collective view of all these circumstances, Sir Isaac Newton concluded, with great confidence, that the deflection toward any planet was the united deflection toward every particle of matter contained in it. This enabled him to determine the intensity of the planetary disturbing forces, by previously ascertaining the proportions of their quantities of matter. This proportion, the discovery of which seems above our reach, is easily ascertained in all those bodies which have others revolving round them: for the deflection of the revolving body, being occasioned by all the matter in the central body, will be proportional (*ceteris paribus*) to the quantity of matter in the central body, and therefore will give us a measure of that quantity. Would we compare the quantity of matter in Jupiter with the quantity of matter in the sun, we have only to suppose that a planet revolves round the sun at the distance of Jupiter's fourth satellite. Kepler's third law will tell us the time of its revolution. The distances, in this case, being the same, the centripetal forces, and consequently the quantities of matter in the central bodies, will be inversely as the squares of the periodic times of the revolutions around them. In this way have the quantities of matter been determined for the Sun, the Earth, Jupiter, Saturn, and the last discovered pla-

net. If the quantity in the Earth be considered as the unit, we have,

The Earth	-	-	-	-	1
The newly discovered planet	-	-	-	-	17,75
Saturn	-	-	-	-	86,16
Jupiter	-	-	-	-	317,1
The Sun	-	-	-	-	338343.

Thus we see that the sun is incomparably bigger than any planet, having more than a thousand times as much matter as Jupiter, the most massy of them all. There is a considerable uncertainty, however, in the proportion to the sun, because we do not know his distance nearer than within $\frac{1}{800}$ th part. The proportions of the rest to each other are more accurate. The quantities of matter in Mercury and Mars can only be guessed at: the quantity in Mercury may be called 0,1, and Mars may be called 0,12. Venus is supposed nearly equal to the Earth. This is concluded from the effect which she produces on the precession of the equinoxes and the equation of the sun's motion. The moon is supposed to be about $\frac{1}{80}$ th of the earth, from the effect she produces on the tides and the precession of the equinoxes, compared with those produced by the sun.

When these quantities of matter are introduced into the computation of the planetary inequalities, and the intensity of the disturbing forces assumed accordingly, the results of the computations tally so exactly with observation, that we can now determine the sun's place for any moment within two or three seconds of a degree, and are certain of the transit of a planet within one beat of the clock!

45
Sun's place and the transit of planet determined exactly.

*Fam dubios nulla caligine prægravat error;
Quæis superum penetrare domos atque ardua cæli
Scandere sublimis genii concessit acumen.*

HALLEY.

Sir Isaac Newton having already made the great discovery of an universal and mutual deflection of all the matter in the solar system, was one day speculating on this subject, and comparing it with other deflections which he observed among bodies, such as magnets, &c. He considered terrestrial gravity as a force of this kind. By the weight of terrestrial bodies they kept united with the earth. By its weight was the water of the ocean formed into a sphere. This force extended, without any remarkable diminution, to the tops of the highest mountains. Might it not reach much farther? May it not operate even at the distance of the moon? In the same manner that the planetary force deflects the moon from the tangent to her orbit, and causes her to describe an ellipse, the weight of a cannon ball deflects it from the line of its direction, and makes it describe a parabola. What if the deflecting force which incurvates her path towards the earth be the simple weight of the moon? If the weight of a body be the same with the general planetary force, it will diminish as the square of its distance from the earth increases. Therefore, said he to himself, since the distance of the moon from the centre of the earth is about 50 times greater than the distance of the stone which I throw from my hand, and which is deflected 16 feet in one second, the weight of this stone, if taken up to the height of the moon, should be reduced to the 2500th part, and should there deflect $\frac{1}{1750}$ th of 16 feet in a second; and the moon should deflect

46
P.ogress of Newton's discovery

deflect as much from the tangent in a second. Having the dimensions, as he thought, of the moon's orbit, he immediately computed the moon's deflection in a second; but he found it considerably different from what he wished it to be. He therefore concluded that the planetary force was not the weight of the planet. For some years he thought no more of it: but one day, in the Royal Society, he heard an account read of measurements of a degree of the meridian, which shewed him that the radius of the earth and the distance of the moon were very different from what he had believed them to be. When he went home he repeated his computation, and found, that the deflection of a stone was to the simultaneous deflection of the moon as the square of the moon's distance from the centre of the earth to the square of the stone's distance. Therefore the moon is deflected by its weight; and the fall of a stone is just a particular instance of the exertion of the universal planetary force. This computation was but roughly made at first; but it was this coincidence that excited the philosopher to a more attentive review of the whole subject. When every circumstance which can affect the result is taken into account, the coincidence is found to be most accurate. The fall of the stone is not the full effect of its weight; for it is diminished by the rotation of the earth round its axis: It is also diminished by the weight of the air which it displaces: It is also diminished by its tendency to the moon. On the other hand, the moon does not revolve round the earth, but round a common centre of the earth and moon, and its period is about $\frac{1}{10}$ th shorter than if it revolved round the earth; and the moon's deflection is affected by the sun's disturbing force. But all these corrections can be accurately made, and the ratio of the full weight of the stone to the full deflection of the moon ascertained. This has been done.

Terrestrial gravity therefore, or that power by which bodies fall or press on their supports, is only a particular instance of that general tendency by which the planets are retained in their orbits. Bodies may be said to *gravitate* when they give indications of their being *gravis* or heavy, that is, when they fall or press on their supports; therefore the planets may be said to gravitate when they give similar indications of the same tendency by their curvilinear motions. The general FACT, that the bodies of the solar system are mutually deflected toward each other, may be expressed by the verbal noun GRAVITATION. Gravitation does not express a quality, but an event, a deflection, or a pressure.

The weight of a terrestrial body, or its pressure on its support, is the effect of the accumulated gravitation of all its particles; for bodies of every kind of matter fall equally fast. This has been ascertained with the utmost accuracy by Sir Isaac Newton, by comparing the vibrations of pendulums made of every kind of matter. Therefore their united gravitation is proportional to their quantity of matter; and we have concluded, that every atom of terrestrial matter is heavy, and equally heavy. We extend this conclusion to the sun and planets, and say, that the observed gravitation of a planet is the united gravitation of every particle. Therefore Sir Isaac Newton inferred, from a collected view of all the phenomena, that *all matter gravitates* to all matter with a force in the inverse duplicate ratio of the distance.

But we do not think that this inference is absolutely

certain. We acknowledge that the experiments on pendulums, consisting of a vast variety of terrestrial matter, all of which performed their oscillations in equal times, demonstrate that the acceleration of gravity on those pendulums was proportional to their quantities of matter, and that equal gravitation may be affirmed of all terrestrial matter.

The elliptical motion of a planet is full proof that the accelerating power of its gravity varies in the inverse duplicate ratio of the distance; and the proportionality of the squares of the periods to the cubes of the distances, shews that the whole gravitations of the planets vary by the same law. But this third observation of Kepler might have been the same, although the gravitation of a particle of matter in Jupiter had been equal to that of a particle of terrestrial matter, provided that all the matter in Jupiter did not gravitate. If $\frac{1}{27}$ th of Jupiter had been such gravitating matter, his deflection from the tangent of his orbit would have been the same as at present, and the time of his revolution would have been what we observe. In order that the third law of Kepler may hold true of the planetary motions, no more is required than that the accumulated gravitation of the planet be proportional to its quantity of matter, and thus the matter which does not gravitate will be compensated by the superior gravitation of the rest.

But because we have no authority for saying that there is matter which gravitates differently from the rest, or which does not gravitate, we are intitled to suppose that gravity operates alike on all matter.

And this is the ultimatum of the Newtonian philosophy, that the solar system consists of bodies composed of matter, every particle of which is, in fact, continually deflected by its weight toward every other particle in the system; and that this deflection, or actual deviation, or actual pressure, tending to deviation from uniform rectilinear motion, is in the inverse duplicate ratio of the distance.

This doctrine has been called *the system of universal gravitation*; and it has been blamed as introducing an unphilosophical principle into science. Gravitation is said to be an occult quality; and therefore as unfit for the explanation of phenomena as any of the occult qualities of Aristotle. But this reproach is unfounded; gravitation does not express any quality whatever, but a matter of fact, an event, an actual deflection, or an actual pressure, producing an actual deflection of the body pressed. These are not occult, but matters of continual observation. True, indeed, Newton does not deny, although he does not positively say, that this deflection, pressure, or gravitation, is an effect having a cause. Gravity is said to be this cause. Gravity is the *being gravis* or heavy, and gravitation is the *giving indications of being heavy*. Heaviness therefore is the word which expresses *gravitas*, and our notion of the cause of the planetary deflections is the same with our notion of heaviness. This may be indistinct and unsatisfactory to a mind fastidiously curious; but nothing can be more familiar. The planet is deflected, *because it is heavy*. We are supposed to explain the fall of a stone through water very satisfactorily, and without having recourse to any occult quality, when we say that it is heavier than the water; and we explain the rise of a piece of cork, when we say that it is not so heavy as the water.

The

48

Which is the ultimatum of his philosophy.

49

Objections to the law of gravitation illustrated.

47

The universal law of gravitation,

The explanations of the mutual actions of the planets are equally satisfactory, founded on the same principles, and equally free from all sophistry or employment of occult causes. The weight of a body is not its heaviness, but the effect of its heaviness. It is a gravitation, an actual pressure, indicated by its balancing the supposed heaviness of another body, or by its balancing the known elasticity of a spring, or by balancing any other natural power. It is similar to the pressure which a magnet exerts on a piece of iron. This may perhaps be produced by the impulse of a stream of fluid; so may the weight of a heavy body. But we do not concern ourselves with this question. We gain a most extensive and important knowledge by our knowledge of this universal law; for we can now explain every phenomenon, by pointing out how it is contained in this law; and we can predict the whole events of the solar system with unerring exactness. This should satisfy the most inquisitive mind.

Our knowledge of that law satisfactory.

But, *nitimur in vetitum, semper cupimusque negata*. There seems to be a fatal and ruinous disposition in the human mind, a sort of *priapism* of the understanding, that is irritated by every interdiction of natural imperfection. We would take a microscope to look at light; we would know what *knowing* is, and we would weigh heaviness.

Vain attempts to account for it.

All who are acquainted with the writings of Aristotle have some notion of his whimsical opinions on this subject. He imagines that the planets are conducted in their orbits by a sort of intelligences, *δενερ ψυχαι*, which animate the orbs that wheel them round. Although this crude conception met with no favour in later times, another, not more reasonable, was maintained by Leibnitz, who called every particle of matter a *monad*, and gave it a perception of its situation in the universe, of its distance and direction from every other, and a power and will to move itself in conformity to this situation, by certain constant laws. This *δενερ ψυχη* in the *Monad* is nothing but an awkward substitute for the principle of gravitation, which the learned insisted that Newton placed in every particle of matter as an innate power, and which they reprobated as unphilosophical. But in what respect this perception and active propensity is better, we do not perceive. It is more complex, and involves every notion that is reprehensible in the other; and it offers no better explanation of the phenomena.

But Newton is equally anxious with other philosophers not to ascribe gravity to matter as an innate inherent property. In a letter to Dr Bently, he earnestly requests him not to charge him with such an absurd opinion. It is an avowed principle, that nothing can act on any thing that is at a distance; and this is considered as an intuitive axiom. But it is surely very obscure; for we cannot obtain, or at least convey, clear notions of the terms in which it is expressed. The word *act* is entirely figurative, borrowed from animal exertions; it is therefore unlike the expression of any thing intitled to the appellation of *intuitive*. If we try to express it without figure, we find our confidence in its certainty greatly diminished. Should we say that the condition of a body A cannot depend on another body B that is at distance from it, we believe that no person will say that he makes this assertion from perceiving the absurdity of the contrary proposition. In the demonstration,

as it is called, of the perseverance of a body in a state of rest, the only argument that is offered is, that no cause can be assigned why it should move in one direction rather than in another: but should any one say that another body is near it, to the right hand, and that this is a sufficient reason for its moving that way, we know no method by which this assertion can be shewn to be false.

Such, however, has been the uniform opinion of philosophers. *Nihil movetur (says Leibnitz) nisi a contigua et moto*. The celebrated mathematician Euler having discovered, as he thought, the production of a pressure, like gravity, from motion, says, "as motion may arise from pressing powers, so we have seen that pressing powers may arise from motion. We see that both exist in the universe. It is the business of a philosopher to discover, by reason and observation, which is the origin of the other. It is incompatible with reason that bodies should be possessed of inherent tendencies; much more that powers should exist independently. Farther, that philosopher must be reckoned to have assigned the true causes of phenomena, who demonstrates that they arise from motion; for motion, once existing, must be preserved for ever. In the present instance (a certain whimsical fact of a ball running round the inside of a hoop) we see how a pressing power may be derived from motion; but we cannot see how powers can exert themselves, or be preserved, without motion. Wherefore we may conclude that gravity, and all other powers, are derived from motion; and it is our business to investigate from what motions of what bodies each observed power derives its origin."

Accordingly many attempts have been made to trace the planetary deflections to their origin in the motion of some impelling matter; but these attempts could not be successful, because they are all built on hypotheses. It has been assumed, that there is a matter diffused through the celestial spaces; that this matter is in motion, and by its impulse moves the planets: but the only reason that can be given for the existence of this matter is the difficulty we find in explaining the planetary deflections without it. Even if the legitimate consequences of this hypothesis were consistent with the phenomena, we have not advanced in our knowledge, nor obtained any explanation. We have only learned, that the appearances are such as would have obtained had such a matter existed and acted in this manner. The observed laws of the phenomena are as extensive as those of the hypothesis; therefore it teaches us nothing but what we knew without it.

But this is not all that can be said against those attempts; *their legitimate consequences are inconsistent with the phenomena*. By legitimate consequences we mean the laws of motion. These must be admitted, and are admitted, by the philosopher who attempts to explain the planetary motions by impulse. It would be ridiculous to suppose a matter to fill the heavens, having laws of impulse different from those that are observed by common matter, and which laws must be contrived so as to answer the purpose. It would be more simple at once to assign those *pro re nata* laws to the planets themselves.

Yet such was the explanation which the celebrated Descartes offered by his hypothesis of vortices, in which the planets were immersed and whirled round the sun.

52
Inconsistency of some of these accounts with the phenomena.

53
Vortices of
Descartes

It is astonishing that so crude a conception ever obtained any partisans; yet it long maintained its authority, and still has zealous defenders. Till Sir Isaac Newton saw the indispensable necessity of mathematical investigation in every question of matter in motion, no person had taken the trouble of giving any thing like a distinct description of those vortices, the circumstances of their motion, and the manner of their action; all determined with that precision that is required in the explanation: for this must always be kept in mind, that we want an explanation of the precise motions *which have been observed*, and which will enable us to predict those which are yet to happen. Men were contented with some vague notion of a *sort* of similarity between the effects of such vortices and the planetary motions in a few general circumstances; and were neither at the trouble to consider how these motions were produced, nor how far they tallied with the phenomena. Their account of things was only fit for careless chat, but unworthy of the attention of a naturalist. But since this explanation came from a person deservedly very eminent, it was respected by Newton, and he honoured it with a serious examination. It is to this examination alone that we are indebted for all the knowledge that we have of the constitution of a fluid vortex, of the motions of which it is susceptible, of the manner in which it can be produced, the laws of its circulation, and the effects which it can produce. We have this account in Sir Isaac Newton's Principles of Natural Philosophy; and it contains many very curious and interesting particulars, which have been found of great service in other branches of mechanical philosophy. But the result of the examination was fatal to the hypothesis; shewing that the motions which were possible in the vortices, and the effects which they must produce, are quite incompatible with the appearances in the heavens. We do not know one person who has acquired any reputation as a mechanician that now attempts to defend it; nor do we know of any other person besides Newton who has attempted to explain mathematically how the circulation of a fluid can produce the revolution of a planet, if we except Mr Leibnitz, the celebrated rival of the British philosopher. This gentleman published in the Leipzig Review in 1689, three years after the publication of the *Principia*, an attempt to explain the elliptical motion of the planets, and the description of areas proportional to the times, by the impulse of a vortex. It must not be passed over in this place, because it acquired great authority in Germany, and many of that country still affirm that Leibnitz is the discoverer of the law of planetary gravitation, and of the mechanical constitution of the solar system. We cannot help thinking this explanation the most faulty of any, and a most disingenuous plagiarism from the writings of Newton.

54
Examined
by Newton.

55
Hypothesis
of Leibnitz

Mr Leibnitz supposes a fluid, circulating round the sun in such a manner that the velocity of circulation in every part is inversely as its distance from the sun. (*N. B.* Newton had shewn that such a circulation was possible, and that it was the only one which could be generated in a fluid by an action proceeding from the centre). Leibnitz calls this *harmonical circulation*. He supposes that the planet adopts this circulation in every part of its elliptical orbit, obeying without any resistance the motion of this fluid. He does not ascribe this to the impulse of the fluid, saying *expressly* that the pla-

net follows its motion, *non abrepta tamen, sed tranquilliter quasi natante*. The planet therefore has no tendency to persevere in its former state of motion. Why therefore does it not follow this harmonic motion exactly, and describe a circle *tranquilliter natans*? This is owing, says Leibnitz, to its centrifugal force, by which it perseveres in a state of rectilinear motion. It has no tendency to preserve its former velocity, but it perseveres in its former direction. The planet therefore is not like common matter, and has laws of motion peculiar to itself; it was needless therefore to employ any impulse to explain its motions. But to proceed: This centrifugal force must be counteracted in every point of the orbit. Leibnitz therefore supposes that it is also urged toward the centre by a sollicitation like gravity or attraction. He calls it the *paracentric force*. He computes what must be its intensity in different parts of the orbit, in order to produce an elliptical motion, and he finds that it must be inversely as the square of the distance from the centre (for this reason he is frequently quoted by Bernoulli, Wolff, and others, as the discoverer of the law of gravitation). But Leibnitz arrives at this result by means of several mathematical blunders, either arising from his ignorance at that time of fluxionary geometry, or from his perceiving that an accurate procedure would lead him to a conclusion which he did not wish: for we have seen (and the demonstration is adopted by Leibnitz in all his posterior writings of this kind), that if the ordinary laws of motion are observed, a body, actuated by this paracentric force alone, will describe an ellipse, performing both its motion of harmonic circulation, and its motion of approach to and recess from the centre, without farther help. Therefore, if the harmonic circulation is produced by a vortex, a force inversely as the square of the distance from the centre, combined with the harmonic circulation, will produce a motion entirely different from the elliptical. It is demonstrated, that the force which is necessary for describing circles at different distances, with the angular velocity of the different parts of the orbit, is not in the inverse duplicate, but in the inverse triplicate, ratio of the distances. This must have been the nature of his paracentric force, in order to counteract the centrifugal force arising from the harmonic circulation. Therefore Leibnitz has not arrived at his conclusion by just reasoning, nor can be said to have discovered it. He says, *Video hanc propositionem innotuisse viro celeberrimo Isaac Newtono, licet non possim judicare quomodo ad eam pervenerit*. This is really somewhat like impudence. The *Principia* were published in 1686. They were reviewed at Leipzig, and the Review published in 1687. Leibnitz was at that time the principal manager of that Review. When Newton published, Leibnitz was living at Hanover, and a copy was sent him within two months of its publication, by Nicholas Facio, long before the Review. The language of the Review has several singularities, which are frequent in Leibnitz's own composition; and few doubt of its being his writing. Besides, this proposition in the *Principia* had been given to the Royal Society several years before, and was in the records before 1684. These were all seen by Leibnitz when in England, being lent him by his friend Collins.

56
Disingenui-
ty of the
author.

We think that the opinion which a candid person must form of the whole is, that Leibnitz knew the proposition,

position, and attempted to demonstrate it in a way that would make it pass for his own discovery; or that he only knew the enunciation, without understanding the principles. His harmonic circulation is a clumsy way of explaining the proportionality of areas to the times; and even this circulation is borrowed from Newton's dissertation on the Cartesian vortices, which is also contained in the Leipzig Review above mentioned. Leibnitz was by this time a competitor with Newton for the honour of inventing the fluxionary mathematics, and was not guiltless of acts of disingenuity in asserting his claim. He published at the same time, in the same Review, an almost unintelligible dissertation on the resistance of fluids, which, when examined by one who has learned the subject by reading the *Principia* of Newton, affords an enigmatical description of the very theory published by Newton, as a necessary part of his great work.

But besides all the above objections to Leibnitz's theory of elliptical motion, we may ask, What is this paracentric force? He calls it like gravity. This is precisely Newton's doctrine. But Leibnitz supposes this also to be the impulse of a fluid. It would have been enough had he explained the action of this fluid, without the other circulating harmonically. He defers this explanation, however, to another opportunity. It must have very singular properties: it must impel the planet without disturbing the other fluid, or being disturbed by it. He also defers to another opportunity the explaining how the squares of the periodic times of different planets are proportional to the cubes of the mean distances; for this is quite incompatible with the harmonic circulation of his vortex. This would make the squares of the periods proportional to the distances. He has performed neither of these promises. Several years after this he made a correction of one of his mathematical blunders, by which he destroyed the whole of his demonstration. In short, the whole is such a heap of obscure, vague, inconsistent assumptions, and so replete with mathematical errors, that it is astonishing that he had the ignorance or the effrontery to publish it.

57
Hypothesis
of Le Sage.

There is another hypothesis that has acquired some reputation. M. le Sage of Geneva supposes, that there passes through every point of the universe a stream of fluid, in every direction, with astonishing velocity. He supposes that, in the densest bodies, the vacuity is incomparably more bulky than the solid matter; so that a solid body somewhat resembles a piece of wire cage-work. The quantity of fluid which passes through will be incomparably greater than that of the intercepted fluid; but the impulse of the intercepted fluid will be sensibly proportional to the quantity of solid matter of the body. A single body will be equally impelled in every direction, and will not be moved; but another body will intercept some fluid. Each will intercept some from the other; and the impulse on B, that is intercepted by A, will be nearly proportional to the matter in A, and inversely proportional to the square of its distance from B; and thus the two bodies will appear to tend toward each other by the law of gravitation.

M. le Sage published this in a work called *Chimie Mécanique*, and read lectures on this doctrine for many years in Geneva and Paris to crowded audiences. It is also published by Mr Prevost in the Berlin Memoirs,

under the name of *Lucrece Newtonien*; and there are many who consider it as a good explanation of gravitation: for our part, we think it inconceivable. The motions of the planets, with undiminished velocity, for more than four thousand years, appears incompatible with the impelling power of this fluid, be its velocity what it will. The absolute precision of the law of gravitation, which does not shew the smallest error during that time, is incompatible with an impulse which cannot be *exactly* proportional to the quantity of matter, nor to the reciprocal of the square of the distance, nor the same on a body moving with the rapidity of the comet of 1680 in its perihelion, as on the planet Saturn, whose motion is almost incomparably slower. What is the origin of the motion of this fluid? Why does it not destroy itself by mutual impulse, since it is continually passing through every point? &c.

We have already observed that Newton expressed the same anxiety to avoid the supposition of action among bodies at a distance. He also seemed to show some disposition to account for gravitation by the action of a contiguous fluid. This is the subterfuge so much resorted to by precipitate speculatists, by the name of the *ether* of Sir Isaac Newton. He supposes it highly elastic, and much rarer in the pores of bodies, and in their vicinity, than at a distance; therefore exceedingly rare in the sun, and denser as we recede from him. Being highly elastic, and repelled by all bodies, it must impel them to that side on which it is most rare; therefore it must impel them toward the sun. This is enough of its general constitution to enable us to judge of its fitness for Newton's purpose. It is wholly unfit; for since it is fluid, unequally dense and elastic, its particles are not in contact. Particles that are elastic, and in a state of compression, and in contact, cannot be fluid; they must be like so many blown bladders compressed in a box; therefore they are not in contact; therefore they are elastic by mutual repulsion; that is, by acting on each other at a distance. It is indifferent whether this distance is a million of miles, or the millionth part of a hair's breadth; therefore this fluid does not free Newton from the supposition which he wishes to avoid. Nay, it can be demonstrated, that in order to form a fluid which shall vary in density from the sun to the extremity of the solar system, there must be a mutual repulsion *extending to that distance*. This is introducing millions of millions of the very difficulties which Newton wished to avoid; for each particle presents the same difficulty with a planet.

58
Ether of
Newton
solves no
difficult-
ties.

We would now ask these atomical philosophers, why they have, in all ages, been so anxious to trace the celestial motions to the effects of impulse? They imagine that they have a clear perception of the communication of motion by impulse, while their perception of the production of it in any other way is obscure. Seeing, in a very numerous and familiar collection of facts, that motion is communicated by impulse, they think that it is communicated in no other way, and that impulse is the only moving power in nature.

But is it true that our notion of impulse is more clear than that of gravitation? Its being more familiar is no argument. A cause may be real, though it has exerted itself but once since the beginning of time. In no case do we *perceive* the exertion of the cause; we only perceive the change of motion. The constitution of our mind

59
Our notion
of impulse
not clearer
than of gravitation.

mind makes us consider this as an effect, indicating a cause which is inherent in that body which we always see associated with that change. Granting that our perception of the perseverance of matter in its state of motion is intuitive, it by no means follows that the body A in motion must move the body B by striking it. The moment it strikes B, all the metaphysical arguments for A's continuance in motion are at an end, and they are not in the least affected by the supposition that A and B should continue at rest after the stroke; and we may defy any person to give an argument which will prove that B will be moved; nay, the very existence of B may, for any thing we know to the contrary, be a sufficient reason for the cessation of the motion of A. The production of motion in B, by the impulse of A, must therefore stand on the same foundation with every other production of motion. It indicates a moving power in A; but this inherent power seems to have no dependence on the motion of A: (See what is contained in n° 81. of the article PHYSICS, and n° 67. of OPTICS of the *Encycl.*) We see there a motion produced in B without impulse, and taken from A, similar in every respect to every case of impulse; and we see that the motion of A is necessary for producing such a motion in B as is observed in all cases of impulse, merely in order that the moving power, which is inherent in A, whether it be in rest or in motion, may act during a sufficient time. Our confidence in the communication of motion, in the case mentioned there, is derived entirely from experience, which informs us that A possesses a moving power totally different from impulse. Our belief of the impelling power of matter therefore does not necessarily flow from our intuitive knowledge of the perseverance of matter, although it gives us the knowledge of this perseverance. It is like a mathematical demonstration, a road to the discovery of the property of figure, but not the cause of that property. The impulsion of matter is merely a fact, like its gravitation, and we know no more of the one than of the other.

It is not a clearer perception, therefore, which has procured this preference of impulsion as the ultimate explanation of motion, and has given rise to all the foolish hypotheses of planetary vortices, ethers, animal spirits, nervous fluids, and many other crude contrivances for explaining the abstruse phenomena of nature.

Nor does it deserve any preference on account of its greater familiarity. Just the contrary; for one fact of undoubted impulse, we see millions where no impulse is observed. Consider the motion produced by the explosion of gunpowder. Where is the original impulse? Suppose the impulse of the first spark of fire to be immense, how comes it that a greater impulse is produced by a greater quantity of gunpowder, a greater quantity of quiescent matter? The ultimate impulse on the bullet should be less on this account. Here are plain exertions of moving powers, which are not reducible to impulse. Consider also the facts in animal motion. Reflect also, that there has been more motion, without any observed impulse, produced in the waters of a river since the beginning of the world, than by all the impulse that man has ever observed. Add to these, all the motions in magnetism, electricity, &c. Impulse is therefore a phenomenon which is comparatively rare.

Have we ever observed motion communicated by pure

impulse, without the action of forces at a distance? This appears to us very doubtful. Every one acquainted with Newton's discoveries in optics will grant, that the colours which appear between two object glasses of long telescopes, when they are pressed together, demonstrate that the glasses do not touch each other, except in the place where there is a black spot. It requires more than a thousand pounds to produce a square inch of this spot. Therefore every communication of motion between two pieces of glass, which can be produced by one of them striking the other, is produced without impulse, unless their mutual pressure has exceeded 1000 pounds on the square inch of the parts which act on each other. Nay, since we see that a black spot appears on the top of a soap bubble, in the middle of the coloured rings, we learn that there is a certain thickness at which light ceases to be visibly reflected; therefore the black spot between the glasses does not prove that they touch in that part; therefore we cannot say that any force whatever can make them touch. The ultimate repulsion may be insuperable. If this be the case, the production of motion by impulse is, in every instance, like the production of motion between the magnets in n° 81. of the article PHYSICS in the *Encycl.* and is of the same kind with the production of motion by gravity.

Therefore no explanation of gravitation can be derived from any hypothesis whatever of intervening fluids. They only substitute millions of bodies for one, and still leave the action *e distanti* the same difficulty as before. It is not in the least necessary that we shall be able to conceive how a particle of matter can be influenced by another at a distance; if we have discovered in every instance the precise degree and direction of the effect of this influence, we have made a most important addition to our knowledge of nature; and our success in the case of the power of gravity should make us assiduous in our endeavours to discover, from the phenomena, the laws which regulate the other actions *e distanti*, which observation is daily finding out. A knowledge equally accurate of the law of magnetic and electric action may enable us to give theories of magnetism and electricity equally exact with the Newtonian theory of gravitation.

Having, we hope, evinced the truth of this theory, by following out the investigations to which Newton was gradually led, we might proceed to consider, in order, the complicated and subordinate phenomena which depend on it. The lunar and planetary inequalities are the subjects that naturally come first in our way; but they have already been explained in all the detail that this concise account will admit, as they occurred to Newton as tests of the truth of his conjecture. If the law be such as he suspected, its consequences must be so and so; if the celestial motions do not agree with them, the law must be rejected. We shall not repeat any thing therefore on this head, but confine our observations to such applications of the theory of universal gravitation, as newly discovered objects, or the improvement of astronomical observation and of fluxionary analysis, have enabled us to make since the time of Newton.

The subserviency of the eclipses of Jupiter's satellites to geography and navigation had occasioned their motions to be very carefully observed, ever since these uses of them were first suggested by Galileo, and their

61
Intervening
fluids mul-
tiplely diffi-
culties.

60
Impulse
rarely ob-
served.

theory is as far advanced as that of the primary planets. It has peculiar difficulties. Being very near to Jupiter, the great deviation of his figure from perfect sphericity makes the relation between their distances from his centre and their gravitations toward it vastly complicated. But this only excited the mathematicians so much the more to improve their analysis; and they saw, in this little system of Jupiter and his attendants, an epitome of the solar system, where the great rapidity of the motions must bring about in a short time every variety of configuration or relative position, and thus give us an example of those mutual disturbances of the primary planets, which require thousands of years for the discovery of their periods and limits. We have derived some very remarkable and useful pieces of information from this investigation; and have been led to the discovery of the eternal durability of the solar system, a thing which Newton greatly doubted of.

62
Eternal durability of the solar system

Mr Pound had observed long ago, that the irregularities of the three interior satellites were repeated in a period of 437 days; and this observation is found to be just to this day.

247	revolutions of the first occupy	437d.	3h.	44'
123	second	437	3	42
61	third	437	3	36
26	fourth	435	14	16

This naturally led mathematicians to examine their motions, and see in what manner their relative positions or configurations, as they are called, corresponded to this period: and it is found, that the mean longitude of the first satellite, *minus* thrice the mean longitude of the second, *plus* twice the mean longitude of the third, always made 180 degrees. This requires that the mean motion of the first, added to twice that of the third, shall be equal to thrice the mean motion of the second. This correspondence of the mean motions is of itself a singular thing, and the odds against its probability seems infinitely great; and when we add to this the particular positions of the satellites in any one moment, which is necessary for the above constant relation of their longitudes, the improbability of the coincidence, as a thing quite fortuitous, becomes infinitely greater. Doubts were first entertained of the coincidence, because it was not indeed accurate to a second. The result of the investigation is curious. When we follow out the consequences of mutual gravitation, we find, that although neither the primitive motions of projection, nor the points of the orbit from which the satellites were projected, were *precisely* such as suited these observed relations of their revolutions and their contemporaneous longitudes; yet, if they differed from them only by very minute quantities, the mutual gravitations of the satellites would in time bring them into those positions, and those states of mean motion, that would induce the observed relations; and when they are once induced, they will be continued for ever. There will indeed be a small equation, depending on the degree of unsuitableness of the first motions and positions; and this causes the whole system to oscillate, as it were, a little, and but a very little way on each side of this exact and permanent state. The permanency of these relations will not be destroyed by any secular equations arising from external causes; such as the action of the fourth satellite, or of the sun, or of a resisting medium; be-

cause their mutual actions will distribute this equation as it did the original error.

This curious result came into view only by degrees, as analysis improved and the mathematicians were enabled to manage more complicated formulas, including more terms of the infinite serieses that were employed to express the different quantities. It is to M. de la Grange that we are indebted for the completion of the discovery of the permanency of the system in a state very little different from what obtains in any period of its existence. Although this required all the knowledge and address of this great mathematician, in the management of the most complicated analysis, the evidence of its truth may be perceived by any person acquainted with the mere elements of fluxionary geometry. The law of the composition of forces enables us to express every action of the mutual forces of the sun and planets by the sines and cosines of circular arches, which increase with an uniform motion, like the perpetual lapse of time. The nature of the circle shows, that the variations of the sines and cosines are proportional to the cosines and sines of the same arches. The variations of their squares, cubes, or other powers, are proportional to the sines or cosines of the doubles or triples, or other multiples of the same arches. Therefore since the infinite serieses which express those actions of forces, and their variations, include only sines and cosines, with their powers and fluxions, it follows, that all accumulated forces, and variations of forces, and variations of variations, through infinite orders, are still expressible by repeated sums of sines or cosines, corresponding to arches which are generated by going round and round the circle. The analyst knows that these quantities become alternately positive and negative; and therefore, in whatever way they are compounded by addition of themselves, or their multiples, or both, we must always arrive at a period after which they will be repeated with all their intermediate variations. It may be extremely difficult, it may be impossible, in our present state of mathematical knowledge, to ascertain all those periods. It has required all the efforts of all the geniuses of Europe to manage the formulas which include terms containing the fourth and fifth powers of the eccentricities of the planetary orbits. Therefore the periods which we have already determined, and the limits to which the inequalities expressed by secular equations arrive, are still subjected to smaller corrections of incomparably longer periods, which arise from the terms neglected in our formulas. But the correction arising from any neglected term has a period and a limit; and thus it will happen that the system works itself into a state of permanency, containing many intervening apparent anomalies. The elliptical motion of the earth contains an anomaly or deviation from uniform circular motion; the action of Jupiter produces a deviation from this elliptical motion, which has a period depending on the configuration of the three bodies; Saturn introduces a deviation from this motion, which has also a period; and so on.

There is another accurate adjustment of motions which has attracted attention, as a thing in the highest degree improbable, in events wholly independent on each other. This is the exact coincidence of the period of the moon's revolution round the earth with that of her rotation round her own axis. The ellipticity or oval shape of the moon differs so insensibly from a sphere, that

that if the original rotation had differed considerably from the period of revolution, the pendular tendency to the earth could never have operated a change: but if the difference between those two motions was so small that the pendular tendency to the line joining the centres of the earth and moon was able to overcome it after some time, the pole of the lunar spheroid would deviate a little from the line joining the earth and moon, and then be brought back to it with an accelerated motion; would pass it as far on the other side, and then return again, vibrating perpetually to each side of the mean position of the *radius vector*. The extent of this vibration would depend on the original difference between the motion of rotation and the mean motion of revolution. This difference must have been very small, because this *pendular vibration* is not sensible from the earth. The observed LIBRATION of the moon is precisely what arises from the inequality of her orbital motion. For the same reasons, the effects of the secular equations of the moon (which would, in the course of ages, have brought her whole surface into our view, had her rotation been strictly uniform) are counteracted by her pendular tendency, which has a force sufficient to alter her rotation by nearly the same slow and insensible changes that obtain in her mean motions. The same causes also preserve the nodes of her equator and of her orbit in the same points of the ecliptic. The complete demonstration of this is perhaps the most delicate and elegant specimen that has been given of the modern analysis. We owe it to M. de la Grange: and he makes it appear that the figure of the moon is not that which a fluid sphere would acquire by its gravitation to the earth; it must be the effect of a more considerable ellipticity, or internal inequality of density.

This permanency of the system, within very narrow limits of deviation from its present state, depends entirely on the law of planetary deflection. Had it been directly or inversely as the distance, the deviations would have been such as to have quickly rendered it wholly unfit for its present purposes. They would have been very great, had the planetary orbits differed much from circles; nay, had some of them moved in the opposite direction. The selection of this law, and this form of the orbits, strikes the mind of a Newton, and indeed any heart possessed of sensibility to moral or intellectual excellence, as a mark of wisdom prompted by benevolence. But De la Place and others, infected with the *Theophobia Gallica* engendered by our licentious desires, are eager to point it out as a mark of fatalism. They say that it is essential to all qualities that are diffused from a centre to diminish in the inverse duplicate ratio of the distance. But this is false, and *very false*: it is a mere geometrical conception. We indeed say, that the density of illumination decreases in this proportion; but who says that this is a quality? Whether it be considered as the emission of luminous corpuscles, or an undulation of an elastic fluid, it is not a quality emanating from a centre: and even in this estimation, it seems gratuitous, whether we shall consider the base of the luminous pyramid, or its whole contents, as the expression of the quantity. Nay, if all qualities must diminish at this rate, all action *e distanti* must do the same; for when the distances bear any great proportion to the diameters of the particles, their action deviates insensibly from this law, and is perceived only by the accumula-

tion of its effects after a long time. It is only thus that the effects of the oblate figure of Jupiter are perceived in the motion of his satellites. The boasted sound philosophy, which sees fatal necessity where the *most successful students of nature* saw moral excellence, has derived very little credit or title to the name of *wisdom*, by letting loose all those propensities of the human heart which are essentially destructive of social happiness. These propensities were always known to lurk in the heart of man; and those surely were the wisest who laboured to keep them in check by the influence of moral principles, and particularly by cherishing that disposition of the human heart which prompts us to see contrivance wherever we see nice and refined adjustment of means to ends; and, from the admirable beauty of the solar system, to cry out,

“These are thy glorious works, Parent of good!
 “Almighty, thine this universal frame,
 “Thus wond’rous fair; thyself how wond’rous then!
 “Unspeaking, who sitt’st above these heavens,
 “To us invisible, or dimly seen
 “In these thy lowest works; yet these declare
 “Thy goodness beyond thought, and power divine.”
 Par. *Loft*, b. v.

“But wandering oft, with brute unconscious gaze,
 “Man marks not THESE, marks not the mighty hand
 “That, ever busy, wheels the silent spheres.”

THOMSON.

The most important addition (in a philosophical view) that has been made to astronomical science since the discovery of the aberration of light and the nutation of the earth’s axis, is that of the rotation of Saturn’s ring. The ring itself is an object quite singular; and when it was discovered that all the bodies which had any immediate connection with a planet were heavy, or gravitated toward that planet, it became an interesting question, what was the nature of this ring? what supported this immense arch of heavy matter without its resting on the planet; what maintains it in perpetual concentricity with the body of Saturn, and maintains its surface in one invariable position?

The theory of universal gravitation tells us what things are possible in the solar system; and our conjectures about the nature of this ring must always be regulated by the circumstance of its gravitation to the planet. Philosophers had at first supposed it to be a luminous atmosphere, thrown out into that form by the great centrifugal force arising from a rotation; but its well defined edge, and, in particular, its being two very narrow rings, extremely near each other, yet perfectly separate, rendered this opinion of its constitution more improbable.

Dr Herschel’s discovery of brighter spots on its surface, and that those spots were permanent during the whole time of his observation, seems to make it more probable that the parts of the ring have a solid connection. Mr Herschel has discovered, by the help of those spots, that the ring turns round its axis, and that this axis is also the axis of Saturn’s rotation. The time of rotation is 10h. 32 $\frac{1}{4}$. But the other circumstances are not narrated with the precision sufficient for an accurate comparison with the theory of gravity. He informs us, that the radii of the four edges of the ring are 590, 751, 774, 830, of a certain scale, and that the angle

63
 Depends on
 the law of
 planetary
 deflection,

64
 And evince
 the wisdom
 of the
 Creator.

65
 Saturn’s
 ring.

66
 Discovery
 of Dr Herschel
 relating to it.

angle subtended by the ring at the mean distance from the earth is $46\frac{2}{3}''$. Therefore its elongation is $23\frac{1}{3}'$. The elongation of the second Cassinian satellite is $56''$, and its revolution is 2d. 17h. 44'. This should give, by the third law of Kepler, 17h. 10' for the revolution of the outer edge of the ring, or rather of an atom of that edge, in order that it may maintain itself in equilibrio. The same calculation applied to the outer edge of the inner ring gives about 13h. 36'; and we obtain 11h. 16' for the inner edge of this ring. Such varieties are inconsistent with the permanent appearance of a spot. We may suppose the ring to be a luminous fluid or vapour, each particle of which maintains its situation by the law of planetary revolution. In such a state, it would consist of concentric strata, revolving more slowly as they were more remote from the planet, like the concentric strata of a vortex, and therefore having a relative motion incompatible with the permanency of any spot. Besides, the rotation observed by Herschel is too rapid even for the innermost part of the ring. We think therefore that it consists of cohering matter, and of considerable tenacity, at least equal to that of a very clammy fluid, such as melted glass.

We can tell the figure which a fluid ring must have, so that it may maintain its form by the mutual gravitation of its particles to each other, and their gravitation to the planet. Suppose it cut by a meridian. It may be in equilibrio if the section is an ellipse, of which the longer axis is directed to the centre of the planet, and very small in comparison with its distance from the centre of the planet, and having the revolution of its middle round Saturn, such as agrees with the Keplerian law. These circumstances are not very consistent with the dimensions of Saturn's inner ring. The distance between the middle of its breadth and the centre of Saturn is 670, and its breadth is 161', nearly one-fourth of the distance from the centre of Saturn. De la Place says, that the revolution of the inner ring observed by Herschel is very nearly that required by Kepler's law: but we cannot see the grounds of this assertion. The above comparisons with the second Cassinian satellite shows the contrary. The elongation of that satellite is taken from Bradley's observations, as is also its periodic time. A ring of detached particles revolving in 10h. $32\frac{1}{3}'$ must be of much smaller diameter than even the inner edge of Saturn's ring. Indeed the quantity of matter in it might be such as to increase the gravitation considerably; but this would be seen by its disturbing the seventh and sixth satellites, which are exceedingly near it. We cannot help thinking therefore that it consists of matter which has very considerable tenacity. An equatorial zone of matter, tenacious like melted glass, and whirled briskly round, might be thrown off, and, retaining its great velocity, would stretch out while whirling, enlarging in diameter and diminishing in thickness or breadth, or both, till the centrifugal force was balanced by the united force of gravity and tenacity. We find that the equilibrium will not be sensibly disturbed by considerable deviations, such as unequal breadth, or even want of flatness. Such inequalities appear on this ring at the time of its disparition, when its edge is turned to the sun or to us. The appearances of its different sides are then considerably different.

Such a ring or rings must have an oscillatory motion round the centre of Saturn, in consequence of their mu-

tual action, and the action of the sun, and their own irregularities: but there will be a certain position which they have a tendency to maintain, and to which they will be brought back, after deviating from it, by the ellipticity of Saturn, which is very great. The sun will occasion a nutation of Saturn's axis and a precession of his equinoxes, and this will drag along with it both the rings and the neighbouring satellites.

The atmosphere which surrounds a whirling planet cannot have all its parts circulating according to the third law of Kepler. The mutual attrition of the planet, and of the different strata, arising from their different velocities, must accelerate the slowly moving strata, and retard the rapid, till all acquire a velocity proportional to their distance from the axis of rotation; and this will be such that the momentum of rotation of the planet and its atmosphere remains always the same. It will swell out at the equator, and sink at the poles, till the centrifugal force at the equator balances the weight of a superficial particle. The greatest ratio which the equatorial diameter can acquire to the polar axis is that of four to three, unless a cohesive force keeps the particles united, so that it constitutes a liquid, and not an elastic fluid like air; and an elastic fluid cannot form an atmosphere bounded in its dimensions, unless there be a certain rarity which takes away all elasticity. If the equator swells beyond the dimension which makes the gravitation balance the centrifugal force, it must immediately dissipate.

If we suppose that the atmosphere has extended to this limit, and then condenses by cold, or any chemical or other cause different from gravity, its rotation necessarily augments, preferring its former momentum, and the limit will approach the axis; because a greater velocity produces a greater centrifugal force, and requires a greater gravitation to balance it. Such an atmosphere may therefore desert, in succession, zones of its own matter in the plane of its equator, and leave them revolving in the form of rings. It is not unlikely that the rings of Saturn may have been furnished in this very way; and the zones having acquired a common velocity in their different strata, will preserve it; and they are susceptible of irregularities arising from local causes at the time of their separation, which may afford permanent spots.

We think that the rotation of Saturn's ring affords some hopes of deciding a very important question about the nature of light. If light be the propagation of elastic undulations, its velocity depends entirely on the elasticity and density of the fluid: but if it be the emission of corpuscles, their velocity may be affected by other causes. The velocity of Saturn's ring is $\frac{2}{3}$ of that of the earth in its orbit, and therefore about $\frac{1}{10000}$ of the velocity of light. The western extremity (to us in the northern regions) is moving from us, and the eastern is moving toward us. If light, by which we see it, be reflected like an elastic ball from an elastic body, there will be an excess in the velocity of the light by which we see the eastern limb above the velocity of the light by which we see the western limb. This excess will be $\frac{1}{10000}$ of the mean velocity of light. This should be discovered by a difference in the refraction of the two lights. If an acromatic prism could be made to refract fourteen degrees, and if Saturn be viewed through a telescope with this prism placed before it, there should

67
Its probable consistency

68
And origin

69
It may furnish the means of discovering the nature of light.

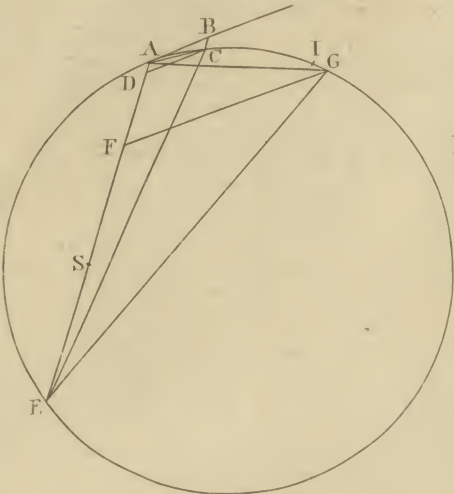


Fig. 1.

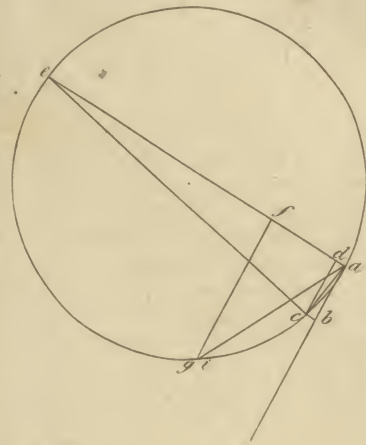


Fig. 2.

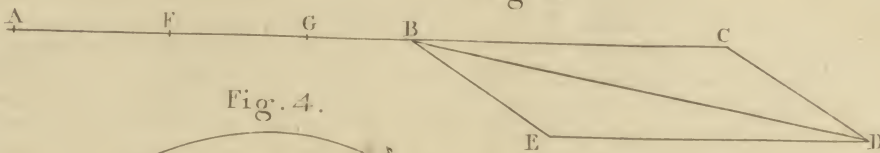


Fig. 3.

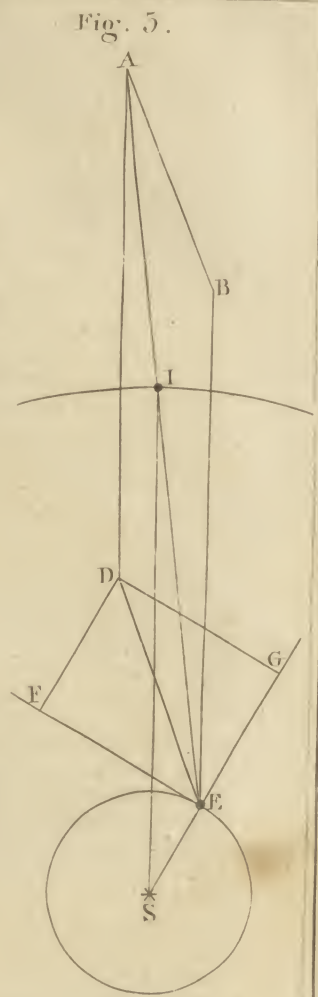


Fig. 4.

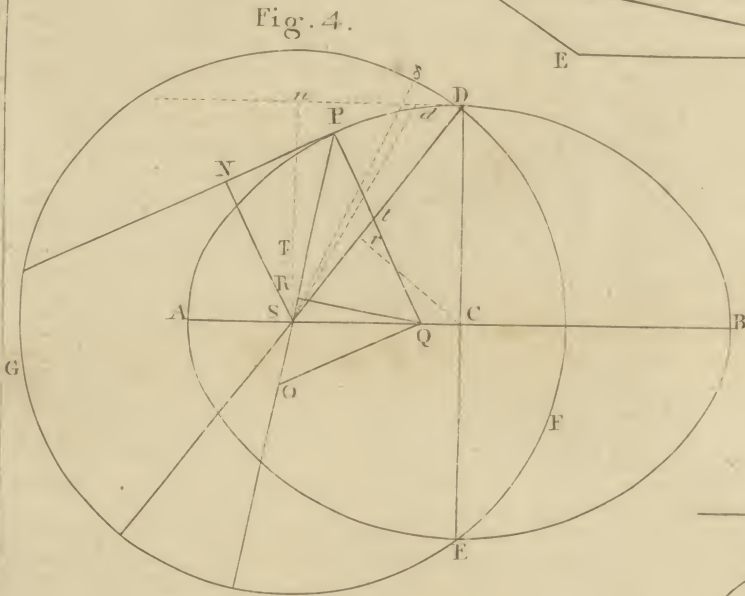


Fig. 5.

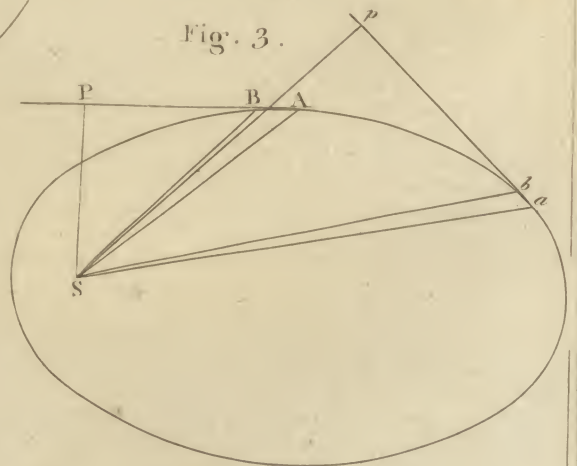


Fig. 6.

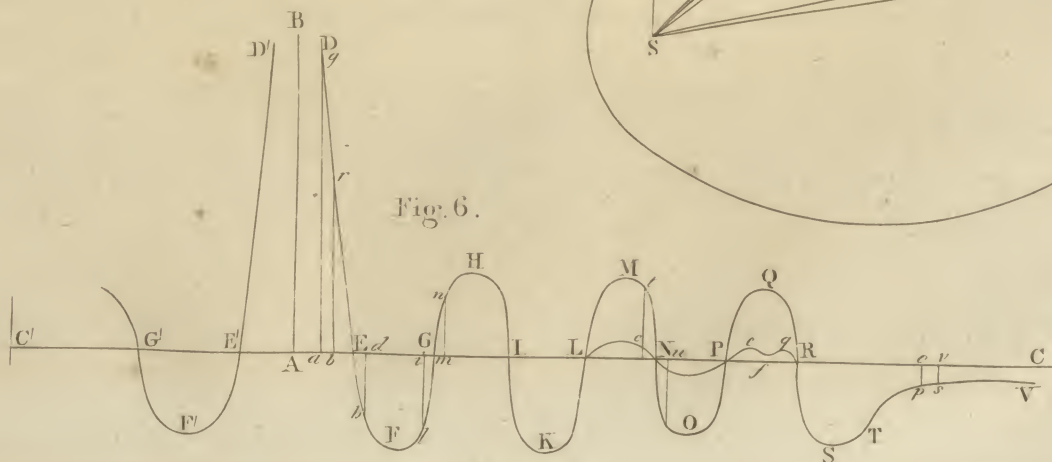
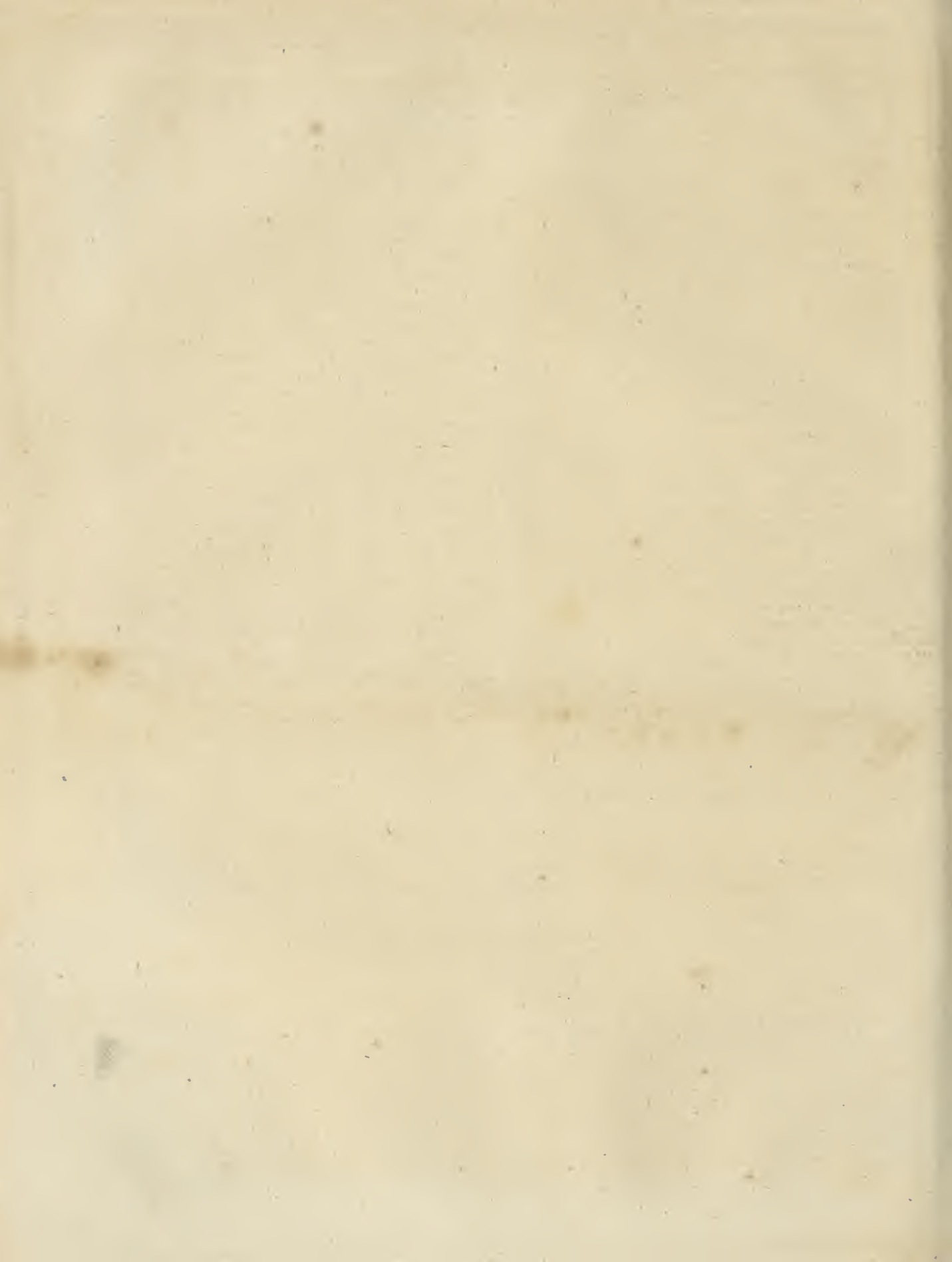


Fig. 7.



be a change of shape amounting to sixteen seconds; if the axis of the prism be parallel to the longer axis of the ring, it will distort it prodigiously, and give it an oblique position.

A similar effect will be produced by placing the prism between the eye-glasses and the image in the focus of the object-glass.

Our expectation is founded on this unquestionable principle in dynamics, that when a particle of light passes through the active stratum of a transparent body which refracts light toward the perpendicular, the addition made to the square of its velocity by the refracting forces is equal to the square of the velocity which those forces would communicate to a particle at rest on the surface of this refracting stratum of the transparent body. Therefore if the velocity of the incident light be increased, the ratio of the sine of incidence to the sine of refraction will be diminished. It is consonant to common sense, that when the incident light has a greater velocity, it passes more rapidly through the attracting stratum, and a smaller addition is made to the velocity. When the velocity of the incident light is 10000 times greater than that of the earth's annual motion, the sine of incidence is to the sine of refraction in glass as 20 to 31, or as 10000 to 15500. If this be increased $\frac{1}{100}$, making it 10004, the ratio will be that of 10004 to 15502.62, or of 10000 to 15496.4. The difference between the refractions of the light from the eastern and western extremities of the ring will be, to all sense, the same, if the velocity of the one be diminished to 9998, and the other increased to 10002.

We may just add here, by the way, that the action of another body may considerably change the constitution of this atmosphere. Thus, supposing that the moon had originally an atmosphere, the limit will be that distance from the moon where the centrifugal force, arising from the moon's rotation, added to the gravitation to the earth, balances the gravitation to the moon. If the moon be $\frac{1}{80}$ th of the earth, this limit will be about $\frac{1}{80}$ th of the moon's distance from the earth. If at this distance the elasticity of the atmosphere is not annihilated by its rarefaction, it will be all taken off by the earth, and accumulate round it. This may be the reason why we see no atmosphere about the moon.

What has been said in the article TIDE (*Encycl.*), will explain the trade-winds on the earth and in Jupiter and Saturn. On the earth they are increased by the expansion of the air by heat. This causes it to rise

in the parts warmed by the sun, and flow off toward the poles, where it is again cooled and condensed. The under stratum of colder and denser air is continually flowing in from the poles. This having less velocity of circulation than the equatorial parts of the earth, must have a relative motion contrary to that of the earth, or from east to west, and this must augment the current produced by gravitation.

Thus we see that all the mechanical phenomena of the solar system, whether relating to the revolutions round the various centres of gravitation, or to the figure of the planets and the oscillations of the fluids which cover them, or to the rotations round their respective axes—are necessary consequences of one simple principle of a gravitation in every particle, decreasing in the reciprocal duplicate ratio of the distance. We see that this, combined with a primitive projection, will produce every motion that we observe. It was not necessary, as Copernicus imagined, to impress three motions on the solar system: one, by which it was made to revolve round the sun; a second, causing it to turn round an axis inclined to that of its orbit; and a third, by which this axis described that conic surface which forms the precession of the equinoxes. One impulse, not passing through the centre of the earth, nor in the plane of the ecliptic, will produce the two first motions, and the protuberant matter produced by the rotation will generate the third motion, by the tendency of its parts to the other heavenly bodies. Without this principle, the elliptic motion of the planets and comets, their various inequalities, secular or periodical, those of the moon and of the satellites of Jupiter, the precession of the equinoxes, the nutation of the earth's axis, the figure of the earth, the undulations of its ocean—all would have been imperfectly known, as matters of fact, wholly different from each other, and solitary and unconnected. It is truly deserving admiration, that such an immense variety of important phenomena flow so palpably from one principle, of such simplicity, and such universality, that no phenomenon is now left out unexplained, and predicted with a certainty almost equal to actual observation.

71
All the mechanical phenomena of the solar system flow from one simple principle.

*Quæ toties animos veterum torfere soporum,
Quæque scholas hodie rauco certamine vexant,
Obvia conspicimus, nubem pellente Mathefi.
Surgite mortales, terrenas mittite curas,
Atque hinc caligenæ vires dignoscite mentis,
A pecudum vitæ longe lateque remotæ.*

A S T

A S Y

ASTROTHEMATA, the places or positions of the stars, in an astrological scheme of the heavens.

ASTROTHERSIA, is used by some for a constellation or collection of stars in the heavens.

ASTRUM, or **ASTRON**, a constellation or assemblage of stars: in which sense it is distinguished from *Aster*, which denotes a single star. Some apply the term, in a more particular sense, to the Great Dog, or rather to the large bright star in his mouth.

ASYMMETRY, the want of proportion, otherwise

called *incommensurability*, or the relation of two quantities which have no common measure, as between 1 and $\sqrt{2}$, or the side and diagonal of a square.

ASYMPTOTES (see *Encycl.*) are, by some, distinguished into various orders. The asymptote is said to be of the first order, when it coincides with the base of the curvilinear figure; of the second order, when it is a right line parallel to the base; of the third order, when it is a right line oblique to the base; of the fourth order, when it is the common parabola, having its axis

Asymptotes.

70
Probable reason why we see no atmosphere about the moon.

Astrothe-
mata
||
Asymme-
try.

axis perpendicular to the base; and, in general, of the $n + 2$ order, when it is a parabola whose ordinate is always as the n power of the base. The asymptote is oblique to the base, when the ratio of the first fluxion of the ordinate to the fluxion of the base approaches to an assignable ratio, as its limit; but it is parallel to the base, or coincides with it, when this limit is not assignable.

ATTAR OF ROSES. See *ROSES*, *Otter of*, both in the Encyclopædia and in this Supplement.

AVANT FOSS, or *Ditch of the Counterscarp*, in fortification, is a wet ditch furrrounding the counterscarp on the outer side, next to the country, at the foot of the glacis. It would not be proper to have such a ditch if it could be laid dry, as it would then serve as a lodgment for the enemy.

AUBIGNE. See *STUART* in this Supplement.

AUMIL, in Bengal, a native collector or manager of a district on the part of government.

AUTENIQUA, a large and beautiful country in Africa, lying to the east of the Cape of Good Hope, and inhabited, part of it, by Dutch colonists. The word *Auteniqua* signifies, in the Hottentot language, "a man loaded with honey:" a name which is not improperly given to the country, since, as you enter it from the Cape, you cannot proceed a step without seeing a thousand swarms of bees. The flowers on which they feed spring up in myriads; and your attention is engaged, and your course suspended, by the mixed odours which exhale from them, by their colours and variety, and by the pure cool air which you breathe. Nature has made these enchanting regions like fairy land. The calyxes of all the flowers abound with excellent juices, from which the bees extract the honey that they everywhere deposit in hollow rocks and trees.

This country was visited in 1782 by M. Vaillant, who calls it the most delightful region in the universe; and says, that, as he approached it, he beheld, from the top of a very high mountain, an immense valley, adorned with agreeable hills, variegated in an infinite number of shapes, and extending in an undulating manner as far as the sea; whilst enamelled meads, and the most beautiful pastures, still added to the magnificent scene. It abounds with small rivulets, which, flowing down from the mountains, run into the sea through an hundred different channels. The water of these rivulets has the colour of Madeira wine, and a ferruginous taste; but our traveller did not examine whether this taste and colour proceed from their flowing through some mine in their passage, or from the roots and leaves of trees which they carry along with them.

The whole of Auteniqua, from the chain of mountains which divides it from the country of that race of Hottentots called *Gonaquas* to the sea, is inhabited by several planters, who rear a number of cattle, make butter, cut down timber, and collect honey; all of which they transport to the Cape: but it appears that they make not the most of their situation. "Can it be believed (says M. Vaillant), that the directors of the Company, for their own use, should order ships to be sent every year from Amsterdam, loaded with planks and boards of every kind, whilst in this country there are immense forests, and the most beautiful trees in the world? This absurdity, however, is not at all astonishing. The Company gratuitously furnishes the gover-

nor and all the officers with whatever wood they have occasion for; and it is delivered to them at their houses without any expence. The governor therefore has no personal interest to extend his views to this part of the administration, and to abolish an abuse so prejudicial to the colony."

But the colonists themselves must be a very indolent and stupid kind of people; since, if our traveller deserves credit, they neglect advantages with which the personal interest of the governor cannot possibly interfere. "I was filled with indignation (says M. Vaillant) to see people, who have wood within their reach, employ it in commerce, and not have the courage to build for themselves habitable houses. They live in wretched hovels, constructed of wicker-work, daubed over with clay; the skin of a buffalo, fixed at the four corners to as many stakes, serves them for a bed; and the door, which is at the same time a window, is shut by a mat; while two or three mutilated chairs, a few pieces of plank, a kind of table, and a pitiful box of two feet square, form all the furniture of these colonial habitations. Thus is the picture of the most profound misery contrasted with the charms of this terrestrial paradise; for the beauties of these regions extend even beyond Auteniqua. The people, however, though their houses be bad, live well. They have game and salt-water fish in abundance; and enjoy exclusively, over all the other cantons of these colonies, the advantage of having, for the whole year without interruption, vegetables of every kind in their gardens. For this they are indebted to the excellence of the soil, and to its being naturally watered by small streams, which cross each other in a thousand different directions, and, as one may say, lay the four seasons under contribution to fertilize Auteniqua. These streams, which frequently overflow their banks, but never dry up, proceed from a cause well known; the high mountains towards the east, which are covered with forests, stop the clouds and the fogs carried from the sea, and this occasions very abundant rains."

In these mountainous regions, which, as well as the plain, our author comprehends under the denomination of *Auteniqua*, there are multitudes of elephants, buffaloes, panthers, hyenas, and antelopes of every species; and all these animals are hunted and killed by the natives, as well for food as for the protection of their flocks and herds from such of them as are beasts of prey. Our author has eaten the flesh of every one of them except the hyena; and declares, that the foot of an elephant, baked after the Hottentot manner, is one of the most delicious morsels that he ever tasted. He gives directions for hunting them all; but warns his readers from attacking elephants when he finds them in droves, for then, he says, they are invincible. He even thinks it exceedingly dangerous for one man, however well armed, to attack a single elephant in the plain. The buffalo he describes, contrary to most other travellers, as a timid animal, which never resists till his situation becomes desperate; and he thinks that there would be no difficulty in training him, if caught when a calf, to the yoke like the bullocks of Europe.

The kites and vultures of this country, our traveller represents as in the highest degree voracious and fierce, in-somuch that it is hardly possible to fright them from their prey. He had on one occasion killed two buffaloes, which

Auteniqua. which he ordered to be cut into very small pieces, that they might be more easily salted, and exposed afterwards to the air and the sun. His wagons, as well as the bushes and trees which surrounded him and his people, were loaded with the bloody fragments of these two animals, and they had begun their operation of salting; but on a sudden, while they were not expecting it, they found themselves attacked by flights of kites and vultures, which, without exhibiting the least symptoms of fear, perched in the midst of them. The kites were above all the most impudent. They seized upon the morsels of flesh, and even contended furiously with his people. "When they had each carried away (says he) a pretty large piece, they retired to some branch, at the distance of ten paces from us, and devoured it before our eyes. Though we fired our fuses they were not frightened, but returned incessantly to the charge; so that finding our powder waited in vain, we resolved to keep them off with large poles until our provisions should be quite dry. This manœuvre, which for a long time harassed my people, did not prevent us from being plundered without mercy; but had we not employed it, nothing would have remained to us of our two buffaloes."

This battle with the kites took place on the confines of the Dutch settlements; but when M. Vaillant had with difficulty passed over the mountains which bound them, the prospects became more magnificent, the soil seemed to be more fruitful and rich, nature appeared to be more majestic and grand, and the lofty mountains presented on all sides more charming and delightful points of view than any that he had ever before met with. These scenes, contrasted with the dry and parched fields of the Cape, made him exclaim, he says, in ecstacy, "What! shall these superb regions be eternally inhabited by tigers and lions? What speculator, with the sordid view only of establishing a kind of centre for commerce, could have preferred the stormy Table Bay to the numberless roads and commodious harbours which are to be found on the eastern coasts of Africa? Thus (continues he) was I reflecting within myself, whilst I was climbing the mountain, and forming vain wishes for the conquest of this beautiful country, which the indolent policy of the European nations will perhaps never gratify."

If his description of its beauties and fertility be not greatly exaggerated, it is indeed wonderful that either the Dutch or some other maritime power of Europe has not long ago taken possession of it. After he had passed the mountain, one could not, he says, choose a more agreeable or advantageous spot than that upon which he then was for establishing a thriving colony. The sea advances through an opening of about a thousand paces in breadth, and penetrates into the country to the distance of more than two leagues and a half. The basin which it forms is more than a league in extent (he does not say whether in breadth or in circumference); and the whole coast, both on the right and the left, is bordered with rocks, which intercept all communication with it. The land is watered by limpid and refreshing streams, which flow down on all sides from the eastern mountains; and these mountains, crowned with majestic woods, extending as far as the basin, and winding round it with a number of sinuosities, exhibit a hun-

dred groves, which are naturally variegated, and each *Auteniqua.* more agreeable than another.

The author proceeding forwards about two days journey, arrived at a bay known to navigators by the name of the Bay of *Agoa*, but called by the colonists *Blettenberg's Bay*, from its having been visited some time before by a Governor Blettenberg, who ordered his name, together with the year and day of his arrival, to be engraven on a stone column. This bay is a little beyond the limits of the country called *Auteniqua*; but it is not foreign from the purpose of this article to insert in this place our traveller's account of it, and of the country around it.

The bay itself, he says, is very spacious, and has a sufficient depth of water for the largest vessels. The anchoring ground is sure, and boats can sail to a beautiful part of the shore, which is not confined by the rocks, as they are all there detached from one another. By advancing a league along the coast, the crews would arrive at the mouth of a considerable river called the *Queur-Boom*, where they would find water. Refreshments might be procured from the inhabitants of the environs; and the bay would supply them with excellent fish, with which it abounds.

This bay is one of those places where government might establish warehouses and repositories for timber; and it is for this reason that we have introduced it to notice in this article. The forests around it, says M. Vaillant, are everywhere magnificent, and the trees could be more easily cut down than anywhere else; for it is not to steep mountains that one must go for wood, as at *Auteniqua*; it is here ready at hand; and during the fine moonsoon might be transported to the Cape with little trouble and no risk. The inexhaustible and fertile lands in the neighbourhood of the bay, if once cultivated, would produce abundant crops, and draw together a great number of intelligent planters, on account of the ready communication which they would have with the Cape. In a word, the Company, continues he, have nothing to do so much for their own interest as to form here a proper establishment. To the general profits of such an institution, would be added those of individuals, which could not fail to be of great importance. They might, for example, cut down a certain tree called *stinking wood*, and export it to Europe, where it would undoubtedly be soon preferred to mahogany and every other kind of wood employed by cabinet makers.

The Hottentots, who in scattered *kraals* inhabit this delightful country, our author describes as a faithful, gentle, and rather timid race. He affirms that they have no religious impressions whatever, nor any notion of superior powers who govern the world. But this, if not a wilful falsehood dictated by the philosophy of France, is probably a mistake arising from his scanty knowledge of their language, and total ignorance of the meaning of their religious ceremonies. His great master, as well as the master of his sect, *Lucretius*, might have taught him, that fear, if not a better principle, will generate the notion of superior beings in the minds of savages; and from fear, by his own account, the inhabitants of *Auteniqua* are far from being free. He likewise affirms, and seems to consider it as much to their credit, that this race of gentle beings, so far from being

Automa
ton

a prey to the passion of jealousy (as other travellers have represented the Hottentots in general), are so obliging, as to lend their wives to travellers who visit them, and that they actually accommodated his Hottentots in this way. Auteniqua, as laid down in M. Vaillant's map, lies between $32^{\circ} 30'$ and $34^{\circ} 50'$ of south latitude, and between 20° and $22^{\circ} 40'$ of east longitude; and his rout through the country was from south-west to north-east, or nearly so.

AUTOMATON. Under this title and that of **ANDROIDES** full credit was allowed in the *Encyclopædia Britannica* to the story of M. de Kempel's mechanical chess-player, and a detail at some length was given of the feats of that figure, as well as of some other surprising automata. No man more readily admits the powers of the skilful mechanic than the writer of this short article; but having many years ago detected the imposition which was practised on the public in some parts of Scotland by a circumforaneous mountebank, who exhibited a figure apparently capable of writing a certain number of words, he has ever since suspected imposture in all automata which appear to have the power of varying their motions according to circumstances. With respect to the chess-player, there is now sufficient evidence that his suspicions were well founded.

In the description of this figure (*Encycl.* Vol. I. p. 787.), "it is said that the automaton could not play unless M. de Kempel or his substitute was near it to direct its moves. A small box during the game was frequently consulted by the exhibitor; and herein consisted the secret, which he said he could in a moment communicate." The secret was indeed simple: "A well taught boy, very thin and small of his age, was concealed in this box almost immediately under the chess-board, and agitated the whole machine." This we learn from Thomas Collinson, Esq; who was let in-

to the secret at Dresden by a gentleman of rank and talents, named *Joseph Fridrick Freyhere*, by whom the vitality and soul of the chess-playing figure had some time before been completely discovered. Mr Collinson, finding that Dr Hutton had given the same credit with us to the reality of mechanical chess-playing, undeceived his friend, by communicating the discovery of Freyhere in a letter, which the Doctor has with great propriety published in the *Addenda* to his *Mathematical Dictionary*. Mr Collinson adds, and we doubt not with truth, that, "even after this abatement of its being strictly an automaton, much ingenuity remains to the contriver." This was in some degree true of the mechanism of the writing figure, of which the compiler of this article detected the bungling imposture of the two exhibitors. The figure itself, with all the principles of its motion, were very ingeniously constructed; but the two men who exhibited it were ignorant and awkward, and could not conceal from a scrutinizing eye, that the automaton wrote sometimes well and sometimes ill, and never wrote at all when they were both present to the company. It was by insisting upon seeing them both together, and threatening to expose the cheat to the whole town, that the present writer prevailed upon him who appeared to be the principal exhibitor, to confess in private that his companion was concealed behind a screen, and to show how, from thence, he directed the movements of the figure.

CONJUGATE AXIS, or *Second Axis*, in the ellipse and hyperbola, is the diameter passing through the centre, and perpendicular to the transverse axis; and is the shortest of all the conjugate diameters.

Transverse Axis, in the ellipse and hyperbola, is the diameter passing through the two foci and the two principal vertices of the figure. In the hyperbola it is the shortest diameter, but in the ellipse it is the longest.

Automa
ton,
Axis.

B.

Bahrdt.

BAHRDT (Dr Carl Friedrich) was so deeply concerned in a combination of philosophers formed, as they said, for the advancement of science and virtue, that an account of his life must be interesting, if it were only to show the effects of this philosophic culture on his own morals. We trust therefore that our readers will be pleased, perhaps improved, by the following narrative, taken from documents the most authentic, by a man* whose communications on other subjects do credit to this volume.

Carl Friedrich Bahrdt was, in 1741, born at Leipzig, where his father, then a parish minister, and afterwards professor of theology, died in 1775. It is natural to suppose that such a parent would be at due pains to instil into the mind of his son the principles of piety, virtue, and patriotism, which is indeed a branch of virtue; but if so, he lived to see that his labour had been

in vain. While yet at college, where the course of his studies was calculated to fit him for the important office of preaching the gospel, the young man enlisted as a hussar in the Prussian service; but being bought off, he returned to the university, where, in 1761, he was admitted to the degree of M. A. Soon afterwards he became catechist in his father's church, was a popular preacher, and in 1765 published sermons, and some controversial writings, which evinced that he possessed both learning and genius. Neither learning nor genius, however, nor both united, could attach him to the cause of virtue, or make him observe even the common rules of decorum; for immediately after this publication he began to indulge in conviviality, and to give scope to his resentments in anonymous pasquinades, in the highest degree bitter and offensive. From the shafts of his malice no person was safe. Professors, magistrates, and

Bahrdt.

* See Professor Robison of Edinburgh's *Proofs of a Conspiracy against all the Religions and Governments of Europe*.

Bahrdr. and clergyman, had indeed his chief notice; but he condescended occasionally to attack students, and spared not even his own comrades or his friends.

Whilst he was thus labouring to make enemies of all to whom he was known, unfortunately, for his own character, his temperament was what the atomical philosophers (who can explain every thing by ethers and vibrations) call sanguine; and he was, as he himself acknowledged, a passionate admirer of the ladies. Coming home from his midnight revels, he frequently met in his way a young girl neatly dressed in a rose-coloured silk jacket and train, and a costly sable bonnet; and one evening, after having, as he says, indulged freely in some old Rhenish, he saw her home to her lodgings. Some time after this interview, the mistress of the house (a Madam Godschufky) came into his room, and said that the poor *maiden* whom he had debauched was pregnant. This was a misfortune *which he could not help*; but as it would ruin his character if known, he gave to the old lady a bond for 200 dahlers (about L. 40 sterling), to be paid by instalments of twenty-five, to keep the matter secret. "The girl (he says) was *sensible* and *good*; and as her conversation, for which he had already paid, was agreeable, he did not discontinue his acquaintance."

It could not be supposed that such visits, by a clergyman, would pass unobserved, however cautiously made, in the midst of a town, of which the inhabitants had been the indiscriminate objects of his satire; and he could hardly be surprised when told by a friend, that one Bel, a magistrate whom he had lampooned, was acquainted with the whole affair, and would bring it into a court of justice, unless the bond was immediately retired.

This bond was the only evidence which could be produced against Bahrdr, but it was sufficient to blast his character in Leipzig, and must therefore by any means be removed out of the way. To accomplish this, however, was a matter of some difficulty; for neither he nor his friend could raise the money. In this dilemma they fell upon a contrivance worthy of themselves. They invited Madam Godschufky to meet them in another house to receive the 200 dahlers due to her by Bahrdr; but when she was ushered into the room, and found no person waiting for her but Bahrdr's friend, she could not be prevailed upon to produce the bond till the money should be put into her hands, together with a present to herself. The *Gentleman* tried to intimidate her. He drew his sword; showed her how men fence; made pushes at the wall and then at her: but finding that she could not be frightened out of her senses, he threw away his sword, and endeavoured to take the bond from her by force. It was some time before he prevailed; but at last getting the paper out of her pocket, he tore it in pieces, opened the door of a closet in which Bahrdr was concealed, and said, "There, you b——; there is the honourable fellow whom you and your whore have bullied; but it is with me you have now to do, and you know that I can bring you to the gallows."

Bahrdr, from whose memoirs of himself this story is taken, admits that there was a great squabble on the occasion; but he went home, comforting himself with the belief that he should now have no farther trouble from Madam Godschufky or her girl. He chanced, however, to be mistaken. The magistrate Bel had some

how been made acquainted with this nefarious transaction, and brought it into court on the day that our hero was to make some very reverend appearance at church. The case of Bahrdr was now hopeless; for after some unsuccessful attempts of his poor father to save him, he was obliged to give in his gown and band, and to quit Leipzig.

To a parent the public disgrace of a child is one of the severest calamities to which human nature is liable; but for this calamity the father of Bahrdr must have been long prepared, as his son appears to have been remarkably undutiful. Of this we have one memorable instance recorded by himself. His father, he says, was severe, and his own temperament hasty, so that he sometimes forgot himself. "One day (continues he) I laid a loaded pistol on the table, and told him that he should meet with that if he went on so; but I was then only SEVENTEEN!"

On his being obliged to leave the place of his nativity, the friends of Bahrdr, and in particular Semler, an eminent theological writer, who had formed a very favourable opinion of his talents, were assiduous in their endeavours to procure an establishment for him elsewhere; but his high opinion of himself, his impetuous and precipitant temper, and that fatirical habit which he had so freely indulged in his outset in life, made their endeavours long ineffectual. At last he got a professorship at Erlangen, then at Erfurth, and in 1771 at Gießen. But in each of these places he was no sooner settled than he got into disputes with his colleagues and with the established church; for he was a strenuous partizan of the innovations then attempted to be made in the doctrines of Christianity. In his publications, which were generally anonymous, he did not trust to rational discussion alone, but had recourse to ridicule and personal anecdotes, and indulged in the most cutting sarcasms and gross scurrility.

His love for convivial company continuing, his income was insufficient for the craving demand. Finding therefore that anecdote and slander always procured readers, and possessing a wonderful activity and facility in writing, he never ceased from publishing lampoons and satires, in which he spared neither friends nor foes. But it was impossible to prevent these publications from being traced to their author; and his avowed theological writings being such as could not be suffered in a professor of divinity, the host of enemies which he had been at so much pains to raise against himself, were furnished with sufficient grounds for subjecting his conduct to legal cognizance; even the very students at Gießen were shocked at some of his liberties.

The consequence of all this was, that, after much wrangling in the church judicatories, he was just about to be dismissed from his professorship, when he got an invitation to Marschlins in Switzerland to superintend an academy.

To Marschlins he went about the year 1776, and began his new career by forming the seminary after the model of an academy which had some time before been set up in the principality of Anhalt Dessau by one Bafedow, a man of talents and learning, who gave to it the appellation of PHILANTHROPINE. The plan of this academy was very different from those of the universities; for its author professed to consider languages, sciences, and the ornamental exercises, as mere accessories,

Bahrtd.

ries, his aim being to form the young mind to the love of mankind and of virtue, by a course of moral education certainly specious, and apparently unexceptionable. To make this novel institution the more extensively useful, the rules by which the education was to be conducted were framed in such a manner as, it was thought, would remove from the minds of Catholics, Lutherans, and Calvinists, all uneasiness respecting the faith of their children, as it related to those particular tenets which separated them into different communions. It was even proposed to banish from the philanthropine all *positive* religion whatever, and to instruct the youth educated there in the principles only of natural, or, as it was called, *philosophical* religion.

This plan was peculiarly suited to Bahrtd's taste, because it left him at liberty to introduce into his academy any system of religious or irreligious opinions that he pleased; a liberty of which he resolved to avail himself, and, though now a doctor in theology, to outstrip, in licentiousness, even the founder of the philanthropine, who was not in orders. By meditating on the workings of his own mind, he had by this time formed his theory of human nature, which was indeed very simple. "The leading propensities of the human mind (he says) are three; instinctive liberty, instinctive activity, and instinctive love." By these expressions we suppose he means, "innate *love* of liberty, instinct prompting to action, and the sexual appetite:" and he immediately adds, that "if a man is obstructed in the gratification of any of these propensities, he suffers an injury. The business therefore of a good education is to teach us how they are to be gratified in the highest degree."

That such an education would be approved of by the uncorrupted natives of Switzerland was hardly to be expected; and Bahrtd soon found his situation at Marschlins as uncomfortable as it had been at Gießen. "The Grisons (he says) were a strong instance of the immense importance of education. They knew nothing but their handicrafts; and their minds were as coarse as their persons." He quarrelled with them all, and was obliged to abscond after lying some time in prison.

From Marschlins he went to Durkheim, a town in the Palatinate, where his father had been minister, and where his literary talents were well known. After some little time he got an association formed for erecting and supporting a *Philanthropine* or house of education. A large fund was collected; and he was enabled to travel into Holland and England to engage pupils, and was furnished with proper recommendations.

In London he gained the friendship of a clergyman, whom he represents as a person in the highest degree accomplished. "With sound judgment (says Bahrtd), great genius, and correct taste, he was perfectly a man of the world. He was my friend, and the only person who warmly interested himself for my institution. To his earnest and repeated recommendations I owe all the pupils that I got in England, and many most respectable connections; for he was universally esteemed as a man of learning and of the most unblemished character. He was my friend, my conductor, and I may say my preserver; for when I had not bread for two days, he took me to his house, and supplied all my wants."

For so much kindness the reader doubtless supposes that the heart of Bahrtd overflowed with gratitude; but if such be his opinion, he is a stranger to the prin-

Bahrtd.

ciples of those who have on the continent of Europe associated for the purpose of enlightening the world. This amiable man, whose character is here so justly drawn, was afterwards depicted by the monster whom he had saved from perishing by hunger, as a wretch lost to all sense of shame and decency, as an apostate from the Christian faith, and as a notorious frequenter of the London brothels! Fortunately he was able to vindicate his character completely from this slanderous abuse, and to convict Bahrtd of having published what *could not possibly be true*.

This ungrateful liar returned from England, and carried into execution his plan of the *Philanthropine*. The castle of Count Leining Hartzburgh at Heidesheim, having gardens, park, and every handsome accommodation, had been fitted up for it; and in 1778 it was consecrated by a solemn religious festival. But his old misfortunes pursued him. He had indeed no colleagues with whom he could quarrel; but his *avowed* publications became every day more obnoxious; and when any of his *anonymous* pieces had a great run, he could not so far stifle his vanity as to conceal that he was the author. Of these pieces some were shocking to decency, and others so horribly injurious to the characters of the most respectable men in the state, that he was continually under the correction of the courts of justice. It was hardly possible for a man of letters to be in his company, and not suffer by it; for it was his constant practice to attribute every step which he took towards atheism, to the force of the arguments urged by some of his friends.

To be his friend, or to obtain his applause, was indeed so great a misfortune, that when the reader sees any person celebrated by Dr Bahrtd, in the beginning of a book, for sound sense, profound judgment, accurate reasoning, or praised for acts of friendship to himself, he may be assured, that before the close of the book this man shall be represented as having in private conversation convinced the author, that some doctrine, cherished and venerated by all Christians, is a piece of knavish superstition.

Dr Bahrtd had married, while at Gießen, a woman with a small fortune: but such a stranger was he to the delicacies of wedded love, so lost indeed to all sense of decency, that he contrived one day to entice his wife *naked* into the bath in the garden of his *Philanthropine*, where, in the water, he, being also *naked*, toyed with her in the sight of all his pupils. It was his boast that he held his opinions independent of all mankind, and was indifferent whether they procured him praise or reproach; but it appears from this fact, that he was equally regardless of the praise or censure which might be attached to his actions; for surely the grossest hog that ever before him batted in the Epicurean sty would not have presented such an exhibition to boys.

The consequence of all this was, that he was obliged to fly from Heidesheim, leaving his sureties in the *Philanthropine* to pay about 14,000 dahlers, besides debts without number to his friends. He was imprisoned at Dienheim; but being soon released, he settled at Halle, where he sunk to be the keeper of a tavern and billiard-table. His house became of course the resort and the bane of the students in the university, and he was obliged to leave the city. He had somehow got money sufficient to purchase a little vineyard, pleasantly situated

Bahr^{dt}. ted in the neighbourhood. This he fitted up with every accommodation that could invite the students, and called it *Bahr^{dt}'s Rube* (Bahr^{dt}'s repose); where he lived for two years, directing the operations of a secret society called the GERMAN UNION, FOR ROOTING OUT SUPERSTITION AND PREJUDICES, AND FOR ADVANCING TRUE CHRISTIANITY.

With Bahr^{dt}'s qualifications for advancing the interests of genuine Christianity, the Christian reader is already sufficiently acquainted; but he will not wonder at his appointment to this high office, when he is informed that the GERMAN UNION is nothing more than a spawn of the secret society of *Illuminati* (see ILLUMINATI in this Supplement); and that its object is to abolish the religion of the gospel, and to teach in its stead the fatalism of the Stoics. With this view Christianity is considered in the UNION as a mystical society, and its Divine Founder as the grand master of a lodge! The apostles Peter, James, John, and Andrew, were the ELECT, brethren of the *third* degree, and initiated into all the mysteries. The remaining apostles were only of the *second* degree; and the seventy-two, of the *first*: a degree into which ordinary Christians may be admitted, and prepared for farther advancement. The great mystery is, that J—C— was a NATURALIST, and taught the doctrine of a supreme mind, the spectator but not the governor of the world.

To propagate these impious and absurd notions, Bahr^{dt} published many books of the most antichristian tendency, and some of them calculated to make their readers shake off all moral obligation. But the labours of the society were not confined to religion: it inculcated on its members the most dangerous maxims of civil conduct: for, as we learn from Bahr^{dt} himself, the objects at which the Union aimed were—*Advancement of science—a general interest and concern for arts and learning—excitement of talents—check of scribbling—good education—LIBERTY—EQUALITY—hospitality—DELIVERY OF MANY FROM MISFORTUNES—union of the learned—and at last—perhaps—Amen.*

What the meaning of this enigmatical conclusion is we can only guess; and we agree with the real philosopher from whom we have taken this account, that our conjectures cannot be favourable. Bahr^{dt} was a villain, and could be associated only with villains, whose affairs he managed with the help of an old man, who lived at bed and board in his house for about six shillings a-week, and discharged the office of secretary to the UNION.

When he had toiled in this cause near two years, some of the secrets of the Union transpired; his former conduct and his constant imprudence made him suspected; his associated friends lodged informations against him; his papers were seized; and he himself was sent to prison, first at Halle and then at Magdeburgh. After something more than a year's confinement, he was set at liberty, and returned to his *Rube*, not, alas! to live at ease, or to exhibit symptoms of repentance, but to lie down on a sick-bed, where, after many months suffering of increasing pain, he died on the 23d of April 1793, the most wretched and loathsome victim of unbridled sensuality.

Such were the fruits of the German Union, and of that illumination which was to refine the heart of man, and bring to maturity the seeds of native virtue, which are choaked in the heart by superstition and despotism.

Dr Bahr^{dt} affected to be the enlightener and reformer of the world; and affirmed that all the evils of life originated from despotism and superstition. "In vain (says he) do we complain of the inefficacy of religion. All positive religion is founded on injustice. No prince has a right to prescribe or sanction any such system; nor would he do it, were not the priests the firmest pillars of his tyranny, and superstition the strongest fetters for his subjects. He dares not show Religion as she is, pure and undefiled—she would charm the eyes and the hearts of mankind, would immediately produce true morality, would open the eyes of freeborn man, would teach him what are his rights and who are his oppressors, and princes would vanish from the face of the earth."

Therefore, without troubling ourselves with the truth or falsehood of his religion of nature, and assuming it as an indisputable point, that Dr Bahr^{dt} has seen it in this natural and so effective purity, it is surely a very pertinent question, "Whether has the sight produced on his mind an effect so far superior to the acknowledged faintness of the impression of Christianity on the bulk of mankind, that it will be prudent to adopt the plan of the German Union, and at once put an end to the divisions which so unfortunately alienate the minds of professing Christians from each other?" The account here given of Dr Bahr^{dt}'s life seems to decide the question.

But it will be said that we have only related so many instances of the quarrels of priests and their slavish adherents with Dr Bahr^{dt}. Let us view him in his ordinary conduct, not as the champion and martyr of illumination, but as an ordinary citizen, a husband, a father, a friend, a teacher of youth, a clergyman.

When Dr Bahr^{dt} was a parish minister, and president of some inferior ecclesiastical district, he was empowered to take off the censures of the church from a young woman who had born a bastard child. By violence he again reduced her to the same condition, and escaped censure by the poor girl's dying of a fever before her pregnancy was far advanced, or even legally documented. On the night of the solemn farce of consecrating his Philanthropine, he debauched the maid-servant, who bore twins, and gave him up for the father. The thing was not judicially proved, but was afterwards made sufficiently evident by letters found among his papers, and published by one of his friends in the UNION. Having supported these infants, in a pitiful manner, for little more than a year, he caused them to be taken away from their mother, during night, some time in the month of February 1780; and they were found exposed, the one at Ustein, and the other at Worms, many miles distant from each other, and almost frozen to death.

So much for the purity of his morals and his religion, as he appears in the character of a father and of a clergyman. His *decency* as a husband, and his gratitude to his friend, we have already seen; and we shall now see his kindness and fidelity. After wasting the greatest part of his wife's little fortune, he was so provoked because her brother would not give him up the remainder, amounting to about L.110, that he ever afterwards treated her with the greatest cruelty, and exhibited her to contempt and ridicule in two infamous novels. At Halle he brought a mistress into the house, and committed to her the care of his family, confining his wife and daughter to their own apartment;

Baird,
Bailly.

Bailly.

apartment; and the last thing which he did was to send for a bookseller, who had published some of his vilest pieces, and, without a thought of his injured wife, recommend his strumpet and her children to his protection.

"Think not, indignant reader (says Arbuthnot), that this man's life is useless to mortals." It shows in a strong light the falsity of all his declamations in favour of his so much praised natural religion and universal kindness and humanity. No man of the party writes with more persuasive energy, and, though his petulance and precipitant self-conceit lead him frequently astray, no man has occasionally put all the arguments of these philosophers in a clearer light; yet we see that all is false and hollow. He is a vile hypocrite, and the real aim of all his writings is to make money, by fostering the sensual propensities of human nature, although he sees and feels that the completion of the plan of the German Union would be an event more destructive and lamentable than any that can be pointed out in the annals of superstition. We will not say that all the partisans of illumination are hogs of the sty of Epicurus like this wretch; and it would be extremely unjust to consider his vices as the effects of his illumination. He was sensual, ungrateful, and profane, before he was admitted into the order of the *Illuminati*; but had the views of that order been such as were held out to the world at large, its sagacious founder would not have initiated a wretch so notoriously profligate as Dr Bahrtd. Their views, however, being to govern mankind thro' the medium of their sensual appetites, and to reign in hell, rather than serve in heaven, they could not have employed a better instrument. Dr Bahrtd was a true disciple of illumination; and though his torch was made of the coarsest materials, and served only to discover fights of woe, the horrid glare darted into every corner, rousing hundreds of filthy vermin, and directing their flight to the rotten carrion, where they could best deposit their poison and their eggs. Whilst the more decent members of the Union laboured to pervert the refined part of mankind by declamations on the rights of man and the blessings of liberty, Bahrtd addressed himself to readers of all descriptions, and assailed at once the imagination and the appetites. He taught them, that religion is an imposture; that morality is convenience; and, with blasphemy peculiar to himself, that he and his order, by their licentious doctrines, were to complete the plan and aim of J—C—.

BAILLY (Jean-Sylvian), who made such a figure during the first years of the French revolution, was born at Paris on the 15th of September 1736, of a family which had been distinguished painters during four successive generations. He was bred to the same profession, but showed an early taste for poetry and the belles lettres. Chancing, however, to become acquainted with the geometer La Caille, this circumstance decided his genius, and he thenceforth devoted himself to the cultivation of science. He calculated the orbit of the comet of 1759; and on the 29th of January 1763 was received into the Academy of Sciences. In that year he published an useful and laborious compilation, being the reduction of the observations made by La Caille in 1760 and 1761, on the zodiacal stars. He likewise began to consider the theory of Jupiter's satellites, and, in the competition for this prize question of 1764, had a

formidable rival in La Grange, who already promised to become the first mathematician in Europe. The results of his investigations were collected into a treatise published in 1766, containing also the history of that part of astronomy. In 1771 he gave a most curious and important memoir on the light of the satellites, and introduced a degree of accuracy till then unknown in the observations of their eclipses.

His studies were not confined to the abstract sciences; for he cultivated letters with success. His eulogies of Charles V. of Cornille, of Leibnitz, of Moliere, and afterward those of Cook, La Caille, and Gresset, were much admired. His eloquence pointed him out as a proper person to fill the charge, vacant in 1771, of secretary to the Academy of Sciences; and, under the patronage of Buffon, he stood candidate for that enviable place. He failed: but it was the high birth and promising talents of the young Condorcet, joined to the active influence of D'Alembert, that carried the prize.

In 1775 appeared the first volume of the History of Astronomy, which indeed strews the path of science with flowers, and in every respect is a most valuable work—full of animated description, of luminous narrative, and interesting detail. His very peculiar ideas concerning the early state of Upper Asia gave rise to an ingenious correspondence and discussion with the veteran philosopher Voltaire, the substance of which soon appeared in two volumes, intitled, "Letters on the Origin of Sciences," and "Letters on the Atlantide of Plato." If imagination shone forth in these essays, erudition was no less conspicuous in a great work composed in the years 1781 and 1782, on the fables and religious creeds of antiquity; which still exists in manuscript, and the publication of which would assuredly extend the fame of its author, and gratify the learned world. His opinions on some points happening to coincide with the theories of Buffon, he contracted with that celebrated naturalist a close friendship, which was dissolved by Bailly's uncourtly opposition to the election of the Abbé Maury into the *Academie Française*. Of that academy he had been chosen secretary in 1784; and he was admitted, in the following year, into the Academy of Inscriptions and Belles Lettres; the only instance, since Fontenelle, of the same person being at once a member of all the three academies. In the meantime, the other volumes of the History of Astronomy successively appeared, and that capital work was completed in 1787 by the History of the Indian and Oriental Astronomy; a production of singular acuteness, research, and nice calculation.

In 1784 he made an elegant report to the Academy of Sciences on the animal magnetism of Mesmer; and in 1786 another report, which displays the judgment and humanity of its author, on a project for a new *hotel-dieu* or infirmary.

We now approach the eventful period which summoned Bailly from his retirement, to enter on a political career, that was full of difficulty and danger, and for which his habits and studies appear not to have fitted him. He had seen, as others saw, the defects of the old government of France. His heart panted for civil and ecclesiastical liberty; but unfortunately, like many other philosophers both in his own country and in this, he had formed notions of that blessing which experience should have taught him can never be realised among beings

Bailly.

ings so imperfect as the bulk of mankind. When the states-general were summoned to meet, he was on the 26th of April 1789 nominated secretary by the electors of Paris, and then appointed one of the deputies. He was chosen president of the *Tiers Etat*; and when that chamber was constituted the National Assembly, he continued in the chair, and concurred in all the levelling decrees which laid the foundation of the present misery of his country, as well of most other countries of Europe.

After the taking of the Bastille, when the king was removed to Paris on the 15th of July, Bailly was called by public acclamation to the head of that city, with the title of *Mayor*. In his several functions he acted with integrity, courage, and moderation. He reached the summit of glory:—but how mutable, alas! is human grandeur! That middle course of conduct, the *auræ mediocritas*, at which virtue aims, is fitted to please neither of the contending parties in the midst of revolutions; and such proved the ruin of Bailly. His popularity began to decline, and was at length changed into inveterate enmity by an unfortunate accident. On the 17th of July 1791, the populace having collected tumultuously to demand the abolition of monarchy, Bailly was ordered by the National Assembly to disperse the mob. He was obliged to proceed to the Champ-de-Mars at the risk of his life; and, in spite of all his exertions and forbearance, some shots were fired by the soldiery. It was no longer desirable to hold his perilous charge, and on the 16th of November following he gave way to the ascending reputation of Petion. The impaired state of his health, too, rendered it expedient to retire from the focus of turbulence. He spent the year 1792 and part of 1793 in travelling through different provinces of France. During this period he wrote memoirs of the events which he had witnessed, and in which he had often been a principal actor. These come down only to the 2d of October 1789, but would make a large quarto volume; and La Lande, from whose *Eloge de Bailly* this article is taken, gives us hopes that the manuscript will be published. He was advised by his friends to withdraw from France, but he chose rather, like Socrates, to submit to the injustice and ingratitude of his country. At the nod of a vulgar tyrant he was arrested, summarily condemned by a sanguinary tribunal, and on the 15th of November 1793 was delivered over to appease the vengeance of an incensed and indiscriminate populace. His sufferings were studiously protracted, but he bore them with the calmness and magnanimity of a sage. Nature recoils at the recital of such barbarities.

In 1787 M. Bailly married the widow of one who had been during 25 years his intimate friend; a woman more qualified by her age and condition to inspire respect than the passion of love. He was tall in his person, of a serious deportment, and joined firmness to sensibility. Never did philosopher distinguish himself in so many different lines, nor acquire such deserved reputation in them all. His disinterestedness was pure and unaffected; and during his magistracy he spent a part of his fortune in relieving the wants of the poor. His virtue remained as untainted in his various public stations as in the sweet retirement of domestic life.

Such is the encomium passed upon this philosopher and statesman by no less a man than the celebrated as-

tronomer M. DE LA LANDE; but to those who are not infected with the *mania* of freedom, it will doubtless appear greatly exaggerated. That M. Bailly was a man of eminence in the republic of letters, is known to all the learned of Europe; that in his political conduct he meant to promote the good of his country, it would certainly be presumptuous in us to deny; and that he suffered unjustly, is incontrovertible: But let it be remembered that he suffered in a storm, which he exerted all his abilities to raise; and that he set an example of injustice, when he concurred in the degradation of the privileged orders, and in the violent confiscation of the property of the church.

BALIOL (John), the competitor with Bruce for the crown of Scotland, was not (as he is said to have been in the *Encyclopædia*) the brother of King ALEXANDER, but the great grandson of David Earl of Huntington, third son of King David I.

BALLISTIC PENDULUM, an ingenious machine invented by Benjamin Robins, for ascertaining the velocity of military projectiles, and consequently the force of fired gunpowder. It consists of a large block of wood, annexed to the end of a strong iron stem, having a cross steel axis at the other end, placed horizontally, about which the whole vibrates together like the pendulum of a clock. The machine being at rest, a piece of ordnance is pointed straight towards the wooden block or ball of this pendulum, and then discharged: the consequence is this—the ball discharged from the gun strikes and enters the block, and causes the pendulum to vibrate more or less according to the velocity of the projectile or the force of the blow; and by observing the extent of the vibration, the force of that blow becomes known, or the greatest velocity with which the block is moved out of its place, and consequently the velocity of the projectile itself which struck the blow and urged the pendulum.

BANKA (see BANCA, *Encycl.*) is noted throughout Asia for its tin mines. It lies opposite to the river Palambang, in the island of Sumatra, on which the sovereignty of Banka, possessor also of the territory of Palambang, keeps his constant residence. This prince maintains his authority over his own subjects, and his independence of the neighbouring sovereigns, chiefly by the assistance of the Dutch, who have a settlement and troops at Palambang, and enjoy the benefit of a contract with the king of Banka for the tin which his subjects procure from that island. Such at least was the case in 1793, when Lord Macartney touched at Banka on his way to China. At that period the sovereign compelled his subjects, and probably does so at present, to deliver the tin to him at a low price, and sold it to the Dutch at a small advance, pursuant to his contract. Those miners, from long practice, have arrived at great perfection in reducing the ore into metal, employing wood as fuel in their furnaces, and not fossile coal, or *coak*, which is seldom so free from sulphur as not to affect the malleability of the metal. It is sometimes preferred therefore to European tin at the Canton market; and the profit upon it to the Dutch company was, at the period mentioned above, supposed to have long been not less than L. 150,000 a year. Into whose hands this trade has now fallen we know not; probably it is in a great degree neglected.

BANTAM, the capital of a kingdom of the same name in the island of Java, is, in the *Encyclopædia*, said

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Bantam.Hutton's
Dictionary.

Bantam
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Barilla

to be a large town with a good harbour and fortified castle. Sir George Staunton, however, who visited Bantam since that article was published, gives a very different account both of the town and of its harbour. Once indeed it was a place of considerable consequence, being the great mart for pepper and other spices, whence they were distributed to the rest of the world. The chief factory of the English as well as Dutch East India Company was settled there. The merchants of Arabia and Hindostan resorted to it. Its sovereigns were so desirous of encouraging trade, by giving security to foreign merchants against the violent and revengeful disposition of the natives, that the crime of murder was never pardoned when committed against a stranger, but might be commuted by a foreigner for a fine to the relations of the deceased. This place flourished for a considerable time; but the Dutch having conquered the neighbouring province of Jacatra, where they since have built Batavia, and transferred their principal business to it, and the English having removed to Hindostan and China, and trade in other respects having taken a new course, Bantam was reduced to a poor remnant of its former opulence and importance. Other circumstances have accelerated its decline. The bay is so choaked up with daily accessions of new earth washed down from the mountains, as well as by coral shoals extending a considerable way to the eastward, that it is inaccessible at present to vessels of burden; even the party who went there from the Lion, the ship which carried Lord Macartney to China, was obliged to remove from her pinnace into a canoe, in order to reach the town. With the trade of Bantam the power of its sovereign declined. In his wars with other princes of Java he called in the assistance of the Dutch; and from that period he became in fact their captive. He resides in a palace built in the European style, with a fort garrisoned by a detachment from Batavia, of which the commander takes his orders not from the king of Bantam, but from a Dutch chief or governor, who lives in another fort adjoining the town, and nearer to the sea-side. His Bantamese majesty is allowed, however, to maintain a body of native troops, and has several small armed vessels, by means of which he maintains authority over some parts of the south of Sumatra. His subjects are obliged to sell to him all the pepper they raise in either island, at a low price, which he is under contract with the Dutch to deliver to them at a small advance, and much under the marketable value of that commodity. The present king joins the spiritual to the temporal power, and is high priest of the religion of Mahomet; with which he mingles, indeed, some of the rites and superstitions of the aboriginal inhabitants of Java; adoring, for instance, the great banyan, or Indian fig-tree, which is likewise held sacred in Hindostan, and under which religious rites might be conveniently performed; in like manner, as all affairs of state are actually transacted by the Bantamese under some shadowing tree by moon-light. To complete the ruin of Bantam, a fire some time ago destroyed most of the houses, and few have been since rebuilt.

BANYAN-TREE. See *FIGUS, Encycl.*

BRITISH BARILLA, is the name given by Mr James King of Newcastle upon Tyne, to a material invented by him to supply the place of Spanish barilla in the making of crown window-glasses, broad window-glasses,

and glass bottles, as also in the manufacturing of soap and alum. For these purposes he affirmed that it answered much better than any other material then in use; and in consequence of that affirmation he obtained a patent for his invention, dated March 4. 1780.

Though we can hardly allow to this invention all the merit claimed for it by its fond author, yet as it may be of use to different manufacturers, we shall lay before our readers his method of making the British barilla. It is as follows: "Take a certain quantity of ashes obtained by burning the loppings or branches of ash, oak, beech, elm, alder, or any other kind of green wood or bramble: Take an equal quantity of the ashes obtained by burning the green vegetables known by the name of fern, brecon, bean and pea-straw, whins, common field and high-way thistles, the stalks of rape or mustard-seed, or the bent or rushes that grow by the sea-shore." Though we know not in what qualities the ashes obtained from the former substances differ from those obtained from the latter, the author, as if the difference was very great, directs these equal quantities to be mixed together, sifted through a fine sieve, and laid upon a boarded floor, where a quantity of soapers waste-ashes, equal to the whole compound mass, is to be added to it, and well mixed with it by means of a shovel or other instrument. To this mixture of vegetable ashes and soapers waste-ashes is to be added a quantity of fine quick-lime, in the proportion of one hundred weight to twelve hundred of the blended ashes, and the lime and ashes are to be well mixed together. After this the whole is to be put into an iron pan, into which is to be poured a quantity of sea-water sufficient, says the author, to dissolve the ashes and lime; and the whole is to be stirred with an iron rake till it incorporate. This being done, a coal fire is to be lighted up under the pan, and kept burning for two days and two nights without intermission, additional quantities of sea-water being constantly supplied to impregnate the materials with saline matter sufficient for calcination in a reverberating furnace or calcar. In this calcar the saline mass, which was boiled in the pan, is by intense heat to be dissolved, and kept in a state of fusion for the space of an hour; during which time the volatile part flies off, and leaves remaining a fixed alkaline salt, which, cooled in iron pans, is the British barilla, and has the appearance of Spanish barilla. See *BARILLA, Encycl.*

BARTHELEMI (Jean Jacques), the Nestor of French literature, was a man so eminent for his knowledge of antiquities, that every classical reader must be interested in his fate. He was born, we believe, at Paris about the latter end of the year 1715; and being educated for the service of the church, he became prior of Courcay, keeper of the medals and antiques in the French king's cabinet, and in 1747 was elected a member of the Academy of Inscriptions. From that period his life was wholly devoted to letters; and in recording the principal events of it, we can only enumerate, in their order, his various publications.

A dissertation of his on the river Pactolus was read 1748 (*Hist. de l'Acad. X. 29.*); Reflections on a Medal of Xerxes, King of Arsamata (*Mem. de l'Acad. XXXVII. 171.*), found, or said to be found, by Fourmont in the temple of Apollo Anacleus (*XXXIX. 129.*); Essay on Numismatic Palæography, *ib.* 223; Dissertation on two Samaritan Medals of Antigonus King

Barilla,
Barthelemi

King of Judea, *ib.* 257; Remarks on some Inscriptions published by different authors, XLV. 99; Dissertation on Arabic Coins, *ib.* 143; by which it appears that the Moliammedan princes copied the heads of Greek and Roman ones on their coins, and gave Arabic inscriptions of their own names on the reverse. On the Ancient Alphabet and Language of Palmyra, *ib.* 179; on the Ancient Monuments of Rome, the result of a tour in Italy to collect medals for the royal cabinet, to which he added 300, XLIX. 151; on some Phœnician Monuments, and the Alphabets formed from them, LIII. 23. The characters on the written mountains, which he here cites, have been proved of no value; and he illustrates the conformity between the Phœnician and the Egyptian characters from the latter on the bandages of the mummies. Explanation of the Mosaic Pavement of the Temple of Prænestè, *ib.* 149; of which there have been four engravings since its first discovery in 1650, and which Barthelemi refers to the voyage of Adrian into Egypt. It may be of that date, but there is no reason to suppose that it represents any thing more than an Egyptian landscape. The form of letters determines the date in the judgment of the learned Abbé. On the Relations of the Egyptian, Phœnician, and Greek Languages, LVII. 383; on some Medals published by different authors, LIX. 270; Explanation of an Inscription under a Bas-relief in the Bishop of Carpentras's Library, 1767, *ib.* 365; on the Number of Pieces represented in one Day on the Theatre at Athens, LXXII. 286; three Comedies, as many Tragedies, a Satire, and a Petite Picce; Remarks on some medals of the Emperor Antoninus struck in Egypt, LXXX. 484. 1775 (A).

His interpretation of the Phœnician inscription at Malta, LIII. 23, was controverted by our learned linguist, Mr Swinton, in *Philos. Transact.* LIV. art. xxii. p. 119; in farther remarks, *ib.* art. lxx. p. 393.

In 1792 he published a dissertation on an ancient Greek inscription, containing an account of expences of the public feasts under the archontate of Glaucippus, 410 years before Christ.

The intimate acquaintance which he had cultivated with classical antiquity, enabled him, in the close of a long life, to compose that *chef-d'œuvre*, the "Travels of the Younger Anacharsis into Greece" in the middle of the fourth century before the vulgar era. In representing the curiosity of a Scythian savage (for we cannot consider in any other light the man who put music and the excesses of the table on the same level), he takes occasion to interweave very curious and instructive details on the laws, religion, manners, customs, and general spirit, of a great nation, as well as its progress in arts and sciences. The epoch which he has chosen is that of letters and arts, combining the age of Pericles with that of Alexander, the revolution which changed the appearance of Greece, and soon after overturned the empire of Persia. The introduction comprehends the 1250 years elapsed from the age of Cecrops to the supposed era of Anacharsis, in two intervals; the first reaching to the commencement of the Olympiads, the second to the capture of Athens by the Lacedæmonians. The

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history of the Athenians commences about 150 years after the first Olympiad, including the age of Solon, or that of legislation; that of Themistocles and Aristides, or that of glory, of luxury, and arts. In the second, speaking of war, his observation, that "the example of one nation, that prefers death to slavery, is too important and too instructive to be passed in silence," should have preserved him from the horrors of a long confinement in an advanced age, from which he was delivered only to die. But arts, sciences, and literature, are alike forgotten and overwhelmed in France. In the third interval, speaking of the corruption of manners introduced by Pericles to support his power, he has this observation, applicable to every state: "Corrupted morals are not restored but by the loss of liberty, which brings that poverty inconsistent with softness, and inseparable from abstemiousness, if not that rigid principle of a healthy mind, which is properly called *virtue*." In this period, though the arts were encouraged, philosophy was neglected.

In this diversified undertaking, where the picture of ancient Greece, in its minutest parts, both of public and private use, is brought before our eyes, the Abbé is frequently more brilliant than solid, and occasionally loses the substance of a reflection in pursuit of something ingenious to add to it. The plans, views, and maps, are executed with great spirit and accuracy by Mr Barber, a young man of very promising talents; and to the charts many useful tables are added. The beauties of the classics are diffused in a very pleasing manner, and interspersed with anecdotes little known.

Such was the man whom the French government detained in prison for months, and released on the fall of Robespierre. As he concurred in the revolution, we know of no cause for his imprisonment but the mildness of his disposition, and the jealousy of that tyrant, which pursued, with relentless cruelty, every man suspected of being a friend to peace. Of the persecution of Barthelemi, in the extremity of old age, the convention itself seemed to be ashamed; for it unanimously voted him a pension as some recompence for his sufferings. But, alas! the recompence came too late: the old man lived but a few months after his liberation, having died at Paris on the 4th of May 1795; and the day after the following tribute was paid to his memory by Duffaulx, in the national convention:

"Legislators, your liberality conferred honour on the latter days of the life of our respectable fellow citizen, Barthelemi. Our successors, I have no doubt, will consecrate his memory so soon as the period fixed by the law shall permit them. May his old friend, however, be permitted, in a few words, to point out the rare qualities of that Nestor of French literature? It might, perhaps, be sufficient to tell you, as Xenophon said with so much simplicity of one of his most illustrious contemporaries, that Barthelemi was an excellent man in all respects. In fact, those who knew him were at a loss which to admire most—his immortal Anacharsis, or his own life. His policy consisted in goodness; his science was an immense treasure of every thing that could purify the morals, perfect the taste, render man

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(A) The references here are to the duodecimo edition of the Memoirs of the Academy of Inscriptions.

Barthelemi
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Bat.

more dear to man, and contribute to the splendour of his country. A single trait will convince you of the mildness of his philanthropic mind: 'Why is it not permitted (he often said) to a mortal to bequeath prosperity to his fellow-creatures?' After having been overwhelmed with the favours of fortune, which came unexpectedly and unfought, he became poor; yet his character, far from sinking under the pressure, acquired new respect; and he proved that poverty, supported with dignity, is not less honourable than wealth accompanied with benevolence. Persecuted, as all virtuous and enlightened citizens were, he carried with him to the dungeon of that tyranny which you have so gloriously destroyed, the constancy and serenity of Socrates. It was there that the venerable old man offered to his companions in misfortune the magnificent spectacle of a good man struggling with adversity. I have said that he was rich; but let us not forget that he was not rich at the expence of the unfortunate, and that he adopted all the branches of his numerous family. The republic has gained by that family good citizens, who serve her in the most useful and brilliant manner. Barthelemi felt that the period of his dissolution was approaching; yet though exhausted by long fatigue, and bending beneath the weight of 80 years, his sensibility was still vigorous, and your just decrees made the closing scene of his life happy. When he heard that you were endeavouring to repair the ills under which so many thousand innocent men laboured, he lifted up his hands to heaven, and exclaimed, 'Glory to God—honour to the national convention—I have lived long enough!' In the present posture of affairs, the country demands all your attention. I shall therefore confine myself to request the favour due to the manes of the illustrious Barthelemi. One of his nephews, I do not mean your respectable ambassador at Basle, but the citizen Courcey, has, for 25 years, discharged all the duties of a son to his uncle, and for a long time has performed the functions of keeper of the medals and antiquities of the national cabinet. I move, that the citizen Courcey be appointed to that office, which he has already proved himself worthy to fill."

Whatever became of this motion, which was referred to the committee of public instruction, the cruelty of the government pursued the family; and the late banishment of his other nephew by the directory, of which he was a member, surpasses, if possible, the injustice of Robespierre to the uncle. But their crimes were the same: both Barthelemis were men of mild dispositions and friends to peace.

BARYTES, one of the earths. See **CHEMISTRY** in this Supplement, Part I. Chap. iv.

BASTER, the name given by the Dutch at the Cape of Good Hope to the offspring of a white man and Hottentot woman.

BAT, an animal which has been described under its generic name *VESPERTILLIO* in the *Encycl.* but since that article was written, we have met with an account of a new species, so very singular, that, if the veracity of our author can be depended on, it is well intitled to a place here. This species was discovered in the country of the Nimiquas, in the interior of Africa, by *M. Vaillant*, during the course of his second travels, and is by him called the *oreillar bat*. To this title it has indeed a very good claim; for it has, he says, four

ears, or at least the external part of four ears, each ear being double; the outer fold, which serves as a covering to the inner, is very ample, being two inches eight lines high, and nearly as broad when stretched out. On the nose also a membrane stands erect, one inch four lines in height, which might be taken for another ear, as it has exactly the shape of one. This membrane, as well as the ears and wings of the animal, are of a rusty red, paler below than above. The body is only three inches long, and is covered with very fine greyish hair. Its width, from the tip of one wing to that of the other, is eight inches. The reader will pardon me, says our author, for inserting these trifling details of measurement, of which I am not more fond than himself; but they appeared to me necessary here, to convey an accurate idea of the extraordinary length of the ears of this animal, which are certainly larger in proportion than those of any other we are acquainted with, since they are only four lines, or the third part of an inch, shorter than the body itself.

BATAVIA, the capital of the Dutch settlements in the East Indies, has been already described under the article **JAVA** in the *Encyclopædia*. The following account of it, however, as well as of the country around it, and the manners and customs of its various inhabitants, as they presented themselves to Sir George Staunton in March 1793, will probably prove acceptable to many of our readers.

The city of Batavia, including the suburbs, consists of near eight thousand houses, inhabited by Dutch, Chinese, and natives of Java. The houses of the Chinese are low, and crammed with people. The Dutch houses are well built, clean, and spacious, and their construction for the most part well suited to the climate. The doors and windows are wide and lofty. The ground floors are covered with flags of marble, which being sprinkled frequently with water, give a pleasant coolness to the apartment; but a considerable proportion of those was untenanted, which denoted a declining settlement. Among other circumstances which announced the same, were those of the Company's vessels lying uselessly in the road, for want of cargoes to fill, or men to navigate them; no ships of war to protect their commerce, even against pirates who attacked their vessels sometimes in the fight of Batavia road; an invasion threatened from the Isle of France; the place in no condition of defence, particularly against an enemy less affected by the climate than Europeans; sometimes as many of the troops in hospitals as fit for duty; commissioners expected from Holland to reform abuses. Such a commission, implying a general suspicion, could not be welcome; nor was it quite certain whether, in some minds, its arrival, or that of the enemy, was deprecated the most cordially.

The fortifications of Batavia, though a place of so much importance, were not, when Sir George saw them, such as would be deemed formidable in Europe; but when the difficulties were considered of forcing the passage of the river, or of landing troops on other parts of the island, it might perhaps be thought of greater strength than it would at the first view have credit for. The defences of the river were the water fort, situated at its entrance, having mounted or dismounted fourteen guns and two howitzers. It consisted of a parapet, originally well constructed, retained by

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by a wall; but the parapet was much neglected, and the wall nearly destroyed by the constant working of the sea. This fort was protected on the land side by a noxious swamp, and towards the sea, on the north-west, by extensive flats, over which even boats could not pass. The only good approach was that by the channel, which it sees and defends. The next work upon the river was on the west shore, about a quarter of a mile from the water fort. It is a battery mounting seven guns, bearing down the river. Opposite to this was a battery of six guns, facing the river, and two to the eastward. This formed one flank of a line that occupied the low land to the north-east of the town. The line was a low breast-work of earth, that was scarcely discoverable. The canals which intersect the town joined the great canal or river, at the distance of half a mile from the entrance. Below the junction a boom was laid of wood, armed with iron spikes. A little above was the castle, a regular square fort, but without ravelins or other outworks. It had two guns mounted on each flank, and two, or sometimes three, on each face: they were not *en barbette*, nor properly *en embrafure*, but in a situation between both, having both their disadvantages without the advantage of either. The wall was of masonry, about 24 feet high. It had no ditch, but a canal surrounded it at some distance. It had no cordon. The length of the exterior side of the work was about 700 feet. The town is rectangular, three quarters of a mile long, and half a mile broad, inclosed by a wall of about 20 feet in height. Small projections were constructed, of various forms, at intervals of about 350 feet. These generally mounted three guns each. It was also furrounded by a canal, having several sluices. At short distances from the town, three or four small star forts of earth were erected in particular passes, perhaps for defence against the inhabitants of the island.

The establishment of regular troops was 1200 Europeans, of whom 300 were to be artillery, the rest infantry. But as it was found impossible, on account of the climate, to keep the number complete, recourse was had to the natives, of whom 500 were employed; so that the establishment of European regulars was reduced to 700. There were also 300 volunteers of the town, who were formed into two companies, but they were not disciplined. Their regulars were very numerous, consisting of enrolled natives of Java, who were never embodied, and of Chinese, of whom the Dutch were so jealous as to arm them with lances only. Much dependence was not to be placed on the exertions of either of these bodies in favour of the Dutch; and as they lose many of their European troops every year, their establishment appeared too small for any effectual resistance. The chief protection of their ill-manned vessels lying here, must be from the fortified island of Onrust, well situated to command the channel that affords the principal passage into the road. The work upon that island was of a pentagonal form; its bastions were small and low, not more than 12 feet the highest, and not always connected by curtains. A few batteries were lately constructed on the outside of this work, that bore towards the sea. On these and on the bastions about 40 guns were mounted in different directions. South of these was another island, at the distance of a few hundred yards, on which two batteries, mounting together 12 guns, had been lately erected.

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The castle is built of coral rock, brought from some of the adjoining islands, composed of that material; and has the advantage of a fortification of brick, in which cannon ball is apt to bury itself without spreading splinters or shattering the wall. A part of the town wall is built of lava, which is of a dark blue colour, of a very hard dense texture, emits a metallic sound, and resembles very much some of the lava of Vesuvius. It is brought from the mountains in the centre of Java, where a crater is still smoking. No stone of any kind is to be found for many miles behind the city of Batavia. Marble and granite are brought thither from China, in vessels belonging to that country, commonly called *junks*, which generally sail for Batavia from the ports of the provinces of Canton and Fokien, on the southern and south-east coasts of that empire, laden chiefly with tea, porcelain, and silks.

The chief protection of Batavia against the attacks of a foreign enemy, arises from the havoc which it is well known the climate would make amongst European troops. This was acknowledged to Lord Macartney by some of the Dutch officers themselves, and even by one of the counsellors of the Indies. Such indeed is the climate, that there have been very few examples of strangers remaining long in Batavia without being attacked by fever, which is the general denomination in that place for illness of every kind. Europeans soon after their arrival first become languid and feeble, and in a few weeks, or even in a few days, are taken feverishly ill. The disorder at first is commonly a tertian ague, which after two or three paroxysms becomes a double tertian, and then a continued remittent, that frequently carries off the patient in a short time. Many fall victims to the second or third fit; but in these cases a constant delirium, and a great determination of the blood to the brain, accompany the other symptoms. In some it begins in a quotidian form, with regular intermissions for a day or two; and then becomes a continued remittent, attended with the same fatal consequences as the former. Of the Europeans of all classes who come to settle at Batavia, it is supposed that not half the number always survives the year. The place resembles in that respect a field of battle or a town besieged. The frequency of deaths renders familiar the mention of them, and little signs are shewn of emotion or surprise on hearing that the companion of yesterday is to-day no more. It is probable, female Europeans suffer less at Batavia than the men. The former seldom expose themselves to the heat of the sun, make frequent use of the cold bath, and live more temperately than the other sex.

But it is not to those who have lately arrived from Europe that this havoc is wholly confined. The greatest number of the Dutch settlers, even those who had resided long in the country, appeared wan, weak, and languid, as if labouring with the "disease of death." Their place of residence, indeed, is situated in the midst of swamps and stagnated pools, from whence they are every morning saluted with "a congregation of foul and pestilential vapours," whenever the sea breeze sets in, and blows over this morass. The meridian sun raises from the shallow and muddy canals, with which the town is intersected, deleterious miasmata into the air; and the trees, with which the quays and streets are crowded, emit noxious exhalations in the night.

The general reputation of the unhealthiness of Batavia

Batavia.

via is indeed such as to deter even Dutchmen, who can reside at home with any comfort, from coming to it, notwithstanding the temptation of fortunes to be quickly amassed in it. From this circumstance it happens, that offices and professions are often necessarily entrusted to persons little qualified to fill them. One of the clergymen, and the principal physician of the place, were both said to have originally been barbers. The United Provinces furnish even few military recruits. The rest are chiefly Germans, many of whom are said to have been kidnapped into the service. Though nominally permitted, after a certain length of time, to return home, they are in fact compelled to enlist for a longer time, the pay being too scanty to allow them to save enough to defray the expence of their passage to Europe. The government is accused of the barbarous policy of intercepting all correspondence between those people and their mother country; by which means they are deprived of the consolation of hearing from their friends, as well as of the chance of receiving such assistance as might enable them to get home.

Difficult, however, as it is, on account of the climate, to recruit the army, such is the desire of accumulating wealth in a foreign land, that it draws annually great numbers of Chinese as well as of Dutch to Batavia. Both indeed belong generally to the humbler classes of life, and are bred in similar habits of industry in their own country; but the different circumstances that attend them after their arrival in Batavia put an end to any further resemblance between them. The Chinese have there no way of getting forward but by the continuance of their former exertions in a place where they are more liberally rewarded, and by a strict economy in the preservation of their gains. They have no chance of advancing by favour, nor are public offices open to their ambition; but they apply to every industrious occupation, and obtain whatever either care or labour can accomplish. They become in town retailers, clerks, and agents; in the country they are farmers, and are the principal cultivators of the sugar-cane. They do at length acquire fortunes, which they value by the time and labour required to earn them. So gradual an acquisition makes no change in their disposition or mode of life. Their industry is not diminished, nor their health impaired. The Dutch, on the contrary, who are sent out by the Company to administer their affairs in Asia, become soon sensible that they have the power, wealth, and possessions of the country at their disposal. They who survive mount quickly into offices that are lucrative, and not to them laborious. They rise to the dignity of governor-general and counsellors of the Indies, as the members of the Batavian government are called. Their influence likewise enables them to speculate in trade with vast advantage. The drudgery and detail of business are readily undertaken by the Chinese; while their principals find it difficult, under such new circumstances, to retain their former habits, or to resist a propensity to indolence and voluptuousness, though often attended with the sacrifice of health, if not of life. Convivial pleasures, among others, are frequently carried to excess.

In several houses of note throughout the settlement, the table is spread in the morning at an early hour: beside tea, coffee, and chocolate, fish and flesh are served for breakfast; which is no sooner over than Madeira,

claret, gin, Dutch small beer, and English porter, are laid out in the portico before the door of the great hall, and pipes and tobacco presented to every guest, and a bright brass jar placed before him to receive the phlegm which the tobacco frequently draws forth. This occupation continues sometimes with little interruption till near dinner time, which is about one o'clock in the afternoon. It is not very uncommon for one man to drink a bottle of wine in this manner before dinner; and those who have a predilection for the liquor of their own country swallow several bottles of Dutch small beer, which they are told dilutes their blood, and affords plenty of fluids for a free perspiration. Immediately before dinner, two men slaves go round with Madeira wine, of which each of the company takes a bumper as a tonic or whetter of the appetite. Then follow three females, one with a silver jar containing water, sometimes rose-water, to wash; a second with a silver basin and low cover of the same metal, pierced with holes, to receive the water after being used; and the third with towels for wiping the hands. During dinner a band of music plays at a little distance: the musicians are all slaves, and pains are taken to instruct them. A considerable number of female slaves attend at table, which is covered with a great variety of dishes; but little is received, except liquors, into stomachs already cloyed. Coffee immediately follows dinner. The 24 hours are here divided, as to the manner of living, into two days and two nights; for each person retires, soon after drinking coffee, to a bed, which consists of a mattress, bolster, pillow, and chintz counterpane, but no sheets; and puts on his night dress, or muslin cap and loose long cotton gown. If a bachelor, which is the case of much the greatest number, a female slave attends to fan him while he sleeps. About six they rise, dress, drink tea, take an airing in their carriages, and form parties to spend the evening together to a late hour. The morning meetings consist generally of men, the ladies seldom choosing to appear till evening.

Few of these are natives of Europe, but many are descended from Dutch settlers here, and are educated with some care. The features and outlines of their faces are European; but the complexion, character, and mode of life, approach more to those of the native inhabitants of Java. A pale languor overspreads the countenance, and not the least tint of rose is seen in any cheek. While in their own houses they dress like their slaves, with a long red checkered cotton gown descending to the ankles, with large wide sleeves. They wear no head-dress, but plait their hair, and fasten it with a silver bodkin on the top of the head, like the country girls in several cantons of Switzerland. The colour of their hair is almost universally black; they anoint it with the oil of the cocoa nut, and adorn it with chaplets of flowers. When they go abroad to pay visits, or to take an airing in their carriages, and particularly when they go to their evening parties, they dress magnificently, in gold and silver spangled muslin robes, with a profusion of jewels in their hair, which, however, is worn without powder. They never attempt to mould or regulate the shape by any fancied idea of elegance, or any standard of fashion; and consequently formed a striking contrast with such few ladies as were lately arrived from Holland, who had powdered hair and fair complexions, had contracted their waists with stays,

wore

Batavia. wore large head-dresses and hoops, and persevered in the early care of forcing back the elbows, chin, and shoulders. Every native lady is constantly attended by a female slave handsomely habited, who, as soon as her mistress is seated, sits at her feet before her, on the floor, holding in her hands her mistress's gold or silver box, divided into compartments, to contain areca nut, cardamom seeds, pepper, tobacco, and slacked lime; all which, mixed together in due proportions, and rolled within a leaf of betel, constitute a masticatory of a very pungent taste, and in general use. When in the public assemblies the ladies find the heat disagreeable, they retire to free themselves from their costly but inconvenient habits, and return without ceremony in a more light and loose attire, when they are scarcely recognizable by strangers. The gentlemen follow the example; and throwing off their heavy and formal dresses, appear in white jackets, sometimes indeed adorned with diamond buttons. The elderly gentlemen quit their periwigs for nightcaps. Except in these moments the members of this government have always combined their personal gratification with the eastern Policy of striking awe into vulgar minds, by the assumption of exterior and exclusive distinctions. They alone, for instance, appear abroad in crimson velvet. Their carriages are distinguished by peculiar ornaments. When met by others, the latter must stop and pay homage to the former. One of the gates of the city is opened only to let them pass. They certainly succeed in supporting absolute sway over a vast superiority in number of the descendants of the original inhabitants of the country, as well as of the slaves imported into it, and of the Chinese attracted to it by the hope of gain; those classes, though healthy, active, and as if quite at home, readily obeying a few emaciated Europeans. Such is the consequence of dominion once acquired; the prevalence of the mind over mere bodily exertions, and the effect of the combination of power against divided strength.

The native Javanese are in general too remote from civilization to have any wants that are not easily satisfied in a warm and fertile climate. No attempt is made to enslave their persons; and they find the government of the Dutch less vexatious than that of others, who divide some share of the sovereignty of the island with them. The sultan of Mataran rules to the east, the emperor of Java in the centre, and the king of Bantam to the west; while the coast and effective power almost entirely belong to Holland. Those other sovereigns are descended from foreigners also; being Arabians, who imported the Mahometan religion into Java, and acquired the dominion of the country; a few inhabitants in the mountains excepted, who have preserved their independence and their faith, and among other articles that of the transmigration of souls. According to the Dutch accounts, nothing can be more tyrannic than those Mahometan rulers. The Emperor is said to maintain his authority by an army of many thousand men dispersed throughout his territories, beside a numerous female guard about his person. These military ladies are trained, it seems, to arms, without neglecting those accomplishments which may occasion a change in the occupation of some among them, rendering them the companions, instead of being the attendants, of his Imperial majesty. This singular institution may owe its origin to the facility of obtaining recruits, if it be

Batavia. true, as the same accounts pretend, that the number of female births exceeds very considerably that of males in Java.

Most of the slaves are imported into it from Celebes and other eastern islands. They do not form a corps, or have any bond of union: nor is the general conduct of their owners towards them calculated to aggravate the misfortune of being the property of others. They are not forced to excessive labour. They have sufficient sustenance; but many of the males among them, who had formerly perhaps led an independent life till made captives in their wars, have been found to take offence against their masters upon very slight occasions, and to wreak their vengeance by assassination. The apprehension of such an event is among the motives for preferring at Batavia female slaves for every use to which they can be applied; so that the number purchased of them much exceeds that of the other sex. The slaves when determined on revenge often swallow, for the purpose of acquiring artificial courage, an extraordinary dose of opium, and soon becoming frantic as well as desperate, not only stab the objects of their hate, but sally forth to attack in like manner every person they meet, till self-preservation renders it necessary to destroy them. They are said in that state to be *running a muck*; and instances of it are not more common among slaves than among free natives of the country, who, in the anguish for losing their money, effects, and sometimes their families, at gaming, to which they are violently addicted, or under the pressure of some other passion or misfortune, have recourse to the same remedy, with the same fatal effects.

In the country round Batavia the eye looks in vain for the common animals and vegetables which it had been daily accustomed to meet in Europe. The most familiar bird about the house of the ambassador's host was the crown bird, as it was called at Batavia, which was not, however, the *ardea pavorina* of Linnæus, but the *columba cristata*, having nothing except its crest in common with the former. The same gentleman had also at his country-house some large cassowary birds, which, though long in his possession, and having the appearance of tameness, sometimes betrayed the fierceness of their nature, attacking with their strong bill those who approached too near them. The vegetation of the country is likewise new. Even the parterres in the gardens are bordered, instead of boxwood, by the Arabian jessamine, of which the fragrant flowers adorn the pagodas of Hindostan. The Dutch, who are so fond of gardens in Holland, have transferred that taste, where it can certainly be cultivated with more success, and indulge it to a great extent at their houses a little way from the city of Batavia; but still within that fenny district, concerning which an intelligent gentleman upon the spot used the strong expression, that the air was pestilential and the water poisonous. Yet the country is everywhere so verdant, gay, and fertile; it is interspersed with such magnificent houses, gardens, avenues, canals, and draw-bridges; and is so formed in every respect to please, could health be preserved in it—that a youth coming just from sea, and enraptured with the beauty of every object he saw around him, but mindful of the danger there to life, could not help exclaiming, "what an excellent habitation it would be for immortals!"

The most tolerable season here is from March or April

Batavia.

pril to November; when the rains begin, and last the rest of the year. The sea breeze sets in about ten o'clock in the morning, and continues till four or five in the afternoon. It becomes then calm till seven or eight, when the land breeze commences, and continues at intervals till day-break, followed by a calm for the remaining hours of the 24. Fahrenheit's thermometer was, in Batavia road, during the Lion's remaining there, from 86° to 88°, and in the town from 88° to 92°; but its variations by no means corresponded to the sensations produced by the heat on the human frame; the latter being tempered by any motion of the air, which circumstance has little effect upon the thermometer. Nor are the animal sufferings here from heat to be measured by its intenseness at any given moment of the day, but by its persisting through the night; when, instead of diminishing, as it does in colder countries, sometimes 20 degrees, it keeps generally here within four or five of what it attains in the shade, when the sun is at its highest elevation.

The native Javanese derive, however, one advantage at least from an atmosphere not subject to the vicissitudes of temperature experienced in the northern parts of Europe, where diseases of the teeth are chiefly prevalent; as they are here entirely exempt from such complaints. Their habit of living chiefly on vegetable food, and of abtaining from fermented liquors, no doubt contributes to this exemption; yet such is the caprice of taste, that jet black is the favourite colour and standard of beauty for the teeth amongst them, comparing to monkeys those who keep them of the natural colour. They accordingly take care to paint, of the deepest black, all their teeth, except the two middle ones, which they cover with gold leaf. Whenever the paint or gilding is worn off, they are as attentive to replace it on the proper teeth, as the belles of Europe are to purify and whiten theirs.

We have mentioned the rich vegetation of the country and the gardens which the Dutch have planted. In these gardens or orchards they cultivate the nutmeg, the clove, the camphor, and the cinnamon trees, together with the pepper plant, which, creeping like a vine, is supported on a living tree. It is a species of the pepper plant that affords the leaf called *betel*, chewed so universally by the southern Asiatics, and serving for the inclosure of a few slices or bits of the areca, from thence erroneously called the *betel nut*. The areca nut tree is among the smallest of the tribe of palms, but comes next in beauty to the mountain cabbage tree of the West Indies, the latter differing chiefly in its size and amazing height from the areca nut tree, the diameter of whose jointed trunk seldom exceeds four inches, or height 12 feet. But the symmetry of each is perfect; the columns of a temple cannot be more regular than the trunk, which rises without a branch, while the broad and spreading leaves which crown the top form the ornamented capital. The areca nut, when dried, has some similitude in form and taste to the common nutmeg, but is of a less size.

It would have been very extraordinary, and very culpable, in Sir George Staunton, and Dr Gillan physician to the embassy, if they had not, when on the spot, inquired into the truth of Foersch's account of the *upas* or poison tree of Java (see *Poison Tree of Java*, *Encycl.*) But the most minute inquiries were made re-

specting it; and the result of them was, that no such tree is known at Batavia, and certainly does not exist where Foersch has planted it. It is indeed a common opinion at Batavia, that there exists in that country a vegetable poison, which, rubbed on the daggers of the Javanese, renders the slightest wounds incurable; though some European practitioners have of late asserted that they had cured persons stabbed by those weapons, but not without having taken the precaution of keeping the wound long open, and procuring a suppuration. One of the keepers of the medical garden at Batavia assured Dr Gillan, that a tree distilling a poisonous juice was in that collection, but that its qualities were kept secret from most people in the settlement, lest the knowledge of them should find its way to the slaves, who might be tempted to make an ill use of it. In the same medical garden, containing it seems hurtful as well as grateful substances, is found also the plant from whence is made the celebrated gout remedy, or moxa of Japan, mentioned in the works of Sir William Temple, and described in the *Encyclopædia* under the titles of *ARTEMISIA* and *MOXA*.

The whole country abounds with esculent fruits, and, amongst others, with the mango-steen, which is ripe in March, and is considered as the most delicious of all fruits (see *GARCINIA*, *Encycl.*) Pine apples are in Java planted not in gardens, but in large fields; and are carried like turneps in heaps upon carts to market, and sold for considerably less than a penny each, where money is cheaper than in England. It was a common practice to clean swords, or other instruments of steel or iron, by running them through pine apples, as containing the strongest and cheapest acid for dissolving the rust that covered them. Sugar sold for about five-pence a pound. All sorts of provisions were cheap, and the ships crews fed on fresh meat every day.

The serpents and noxious reptiles in Java have been mentioned elsewhere; but Sir George Staunton assures us, that not many accidents happen from them. Among the pagan Javanese, the crocodile, he says, is an object not only of fear, but also of religious veneration, to which offerings are made as to a deity. When a Javanese feels himself diseased, he will sometimes build a kind of coop, and fill it with such eatables as he thinks most agreeable to the crocodiles. He places the coop upon the bank of the river or canal, in the perfect confidence that, by the means of such offerings, he will get rid of his complaints; and persuaded, that if any person could prove so wicked as to take away those viands, such person would draw upon himself the malady for the cure of which the offering was made. According to Sir George Staunton, Batavia road lies in 6° 10' south lat. and 106° 51' east long. from Greenwich.

BEER is a liquor so palatable to the natives of Britain, and, when properly made, so wholesome, especially in long voyages at sea, that Mr Thornton of East Smithfield obtained a patent, dated April 15. 1778, for inventing a method of reducing *malt* and *hops* to an essence or extract, from which beer may be made anywhere, either at sea or in distant countries. Though we do not perceive any great degree of ingenuity displayed in this invention, yet as the account of it is short, we shall lay it before our readers.

His method then of preparing an essence or extract of malt and hops is, by the transmitted heat of compressed

Batavia,
Beer.

Beetle.

pressed vapour of boiling water, and a proper apparatus for that purpose. This apparatus may be made of iron, tin, or copper: it consists of a boiler of any dimensions, a double vessel, and conducting tubes. The double vessel consists of one vessel placed within another, and fitted tight at their rims. The upper vessel forms the upper part of the under vessel, and contains the liquor to be evaporated. The under vessel is everywhere inclosed except at an aperture communicating with the boiler, and at another aperture communicating with the conducting tubes; and is constructed so as not to allow any part of the vapour condensed into drops within it to escape, except back again into the boiler: it is not so extensive as to act as a common refrigeratory, and yet is capacious enough to prevent the liquor boiling over. The aperture communicating with the boiler is large enough to freely admit the vapour from the boiler into the under vessel; and the aperture communicating with the conducting tubes is of a proper size to allow of the vapour in the under vessel being compressed, to a degree capable of transmitting to the liquor to be evaporated a proper heat, and at the same time to serve as a passage for more heat than is necessary to keep up that degree of compression. The conducting tubes are to convey this superfluous heat or vapour, to be used for farther purposes, or immediately out of the building.

BEETLE, an insect described in the Encyclopædia under the name given to it by naturalists, *SCARABÆUS*. Since that article was published, we have met with an account of a nondescript species, which is furnished with very singular armour for its own defence. It was brought to M. Vaillant in the interior parts of Africa by a Nimiqua woman, and is by him called a superb beetle, not to be found in any cabinet of Europe. "While I was examining this beautiful insect (says he) with attention, I felt my face suddenly wetted by a caustic liquor, of a very strong alkaline smell. The sprinkling was accompanied by a sort of explosion, loud enough to be heard at some distance. Unfortunately some of the liquor entered one of my eyes, and occasioned such insupportable pain, that I thought I should have lost the sight of it. I was obliged to keep it covered for several days, and bathe it from time to time with milk. In every part of my face that the alkaline liquor had touched, I felt the pain of a burn; and everywhere the skin changed to a deep brown, which wore out only by degrees and a long time after. This will not be surprising to many, who already are acquainted with the same property in several insects of the same genus; for instance, in that beautiful golden green buprestis, which is so common in our kitchen gardens in Europe: but as the insect of which I am here speaking is much larger, and inhabits a very hot country, it is natural that the effect produced by it should be more striking; tho' the liquor which our golden buprestis ejects at its enemy

occasions a very sensible smart, and its smell is considerably pungent."

The naturalists Dorci and Olivier have given, in their Entomology, the figure of this African insect, which our author communicated to them, but they have given it erroneously. The human face, observable on its anterior corcelet in their figure, does not exist in nature; but M. Vaillant having given no figure of it himself, we cannot gratify our readers with a correct representation.

BEGAH, a land measure in Bengal, about one-third of an English acre.

BEHADER (*Valiant*), a title of honour conferred by the Mogul emperors upon either Mahomedans or Hindoos, and placed after their name or other title.

BEHEM (Martin), though hitherto little talked of, was one of the most enterprising men that ever lived, and deserves to have his name transmitted with reverence to the latest posterity. Born at Nuremberg, an Imperial city in the circle of Franconia, of a noble family not yet extinct, he had the best education which the darkness of that age would permit him to have; and the studies to which from his infancy he was most addicted, were those of geography, astronomy, and navigation. As he advanced in life, he often thought of the existence of the antipodes and of a western continent, of which he was ambitious to make the discovery.

Filled with this great idea, in 1459 he paid a visit to Isabella, daughter of John I. king of Portugal, at that time regent of the duchy of Burgundy and Flanders; and having informed her of his designs, he procured a vessel, in which, sailing westward, he was the first European who is known to have landed on the island of Fayal. He there established in 1460 a colony of Flemings, whose descendants yet exist in the Azores, which were for some time called the Flemish Islands. This circumstance is proved, not only by the writings of contemporary authors, but also by the manuscripts preserved in the records of Nuremberg; from the Latin of which the following is translated: "Martin Behem tendered his services to the daughter of John king of Lusitania, who reigned after the death of Philip of Burgundy, surnamed the *Good*; and from her procured a ship, by means of which, having sailed beyond all the then known limits of the Western Ocean, he was the first who in the memory of man discovered the island of Fayal, abounding with beech trees, which the people of Lusitania call *faye*; whence it derived its name. After this he discovered the neighbouring islands, called by one general name the *Azores*, from the multitude of hawks which build their nests there (for the Lusitanians use this term for hawks, and the French too use the word *effos* or *esores* in their pursuit of this game); and left colonies of the Flemish on them, when they began to be called Flemish Islands (A)."

After

(A) Although this record is contrary to the generally received opinion, that the Azores were discovered by Gonfalva Velho, a Portuguese, yet its authenticity seems unquestionable. It is confirmed not only by several contemporary writers, and by Wagenfeil, one of the most learned men of the last century, but likewise by a note written on parchment in the German language, and sent from Nuremberg, a few years ago, to M. Otto, who was then investigating the discovery of America. The note contained, with other things, the following facts: "Martin Beham, Esq; son of Mr Martin Beham of Scoperin, lived in the reign of John II. king of Portugal, in an island which he discovered, and called the island of *Fayal*, one of the Azores, lying in the Western Ocean."

Bengala

Behem.

Behem.

After having obtained from the regent a grant of Fayal, and resided there about twenty years, Behem applied in 1484 (eight years before Columbus's expedition) to John II. king of Portugal, to procure the means of undertaking a great expedition towards the south-west. This prince gave him some ships, with which he discovered that part of America which is now called Brazil; and he even sailed to the Straits of Magellan, or to the country of some savage tribes whom he called Patagonians, from the extremities of their bodies being covered with a skin more like a bear's paws than human hands and feet.

A fact so little known, and apparently so derogatory to the fame of Columbus, ought not to be admitted without sufficient proof; but the proofs which have been urged in support of its authenticity are such as cannot be controverted. They are not only the letters of Behem himself, written in 1486, and preserved in the archives of Nuremberg, but likewise the public records of that city; in which we read that "Martin Behem, traversing the Atlantic Ocean for several years, examined the American islands, and discovered the strait which bears the name of Magellan before either Christopher Columbus or Magellan sailed those seas; whence he mathematically delineated, on a geographical chart, for the king of Lusitania, the situation of the coast around every part of that famous and renowned strait long before Magellan thought of his expedition."

This wonderful discovery has not escaped the notice of contemporary writers. The following passage is translated from the Latin chronicle of Hartman Schedl: "In the year 1485, John II. king of Portugal, a man of a magnanimous spirit, furnished some galleys with provisions, and sent them to the southward, beyond the Straits of Gibraltar. He gave the command of this squadron to James Canus, a Portuguese, and Martin Behem, a German of Nuremberg in Upper Germany, descended of the family of Bonna: a man very well acquainted with the situation of the globe; blessed with a constitution able to bear the fatigues of the sea; and who, by actual experiments and long sailing, had made himself perfectly master with regard to the longitudes and latitudes of Ptolemy in the west. These two, by the bounty of Heaven, coasting along the Southern Ocean, and having crossed the equator, got into the other hemisphere, where, facing to the eastward, their shadows projected towards the south and right hand. Thus, by their industry, they have opened to us another world hitherto unknown, and for many years attempted by none but the Genoese, and by them in vain. Having finished this cruise in the space of 26 months, they returned to Portugal with the loss of many of their seamen by the violence of the climate."

Besides this evidence of the first discovery of America having been made by Behem, we find the following particulars in the remarks made by Petrus Mateus on the canon law, two years before the expedition of Columbus: "*Prima navigationes*, &c. The first Christian voyages to the newly discovered islands became frequent under the reign of Henry, son of John, king of Lusitania. After his death Alphonfus V. prosecuted the design; and John, who succeeded him, followed the plan of Alphonfus, by the assistance of Martin Behem, a very skilful navigator; so that in a short time the name of Lusitania became famous over the whole world."

Cellarius, one of the most learned men of his age, says expressly, "*Behaimus non modo*, &c. Behem did not think it enough to survey the island of Fayal, which he first discovered, or the other adjacent islands which the Lusitanians call *Azores*, and we, after the example of Behem's companions, call *Flemish* islands, but advanced still farther and farther south, until he arrived at the remotest strait, through which Ferdinand Magellan, following his track, afterwards sailed, and called it after his own name."

All these quotations, which cannot be thought tedious, since they serve to prove a fact almost unknown, seem to demonstrate, that the first discovery of America is due to the Portuguese and not to the Spaniards; and that the chief merit belongs to a German astronomer. The expedition of Ferdinand Magellan, which did not take place before the year 1519, arose from the following fortunate circumstance: This person, being in the apartment of the king of Portugal, saw there a chart of the coast of America drawn by Behem, and at once conceived the bold project of following the steps of this great navigator. Jerome Benzon, who published a description of America in 1550, speaks of this chart; a copy of which, sent by Behem himself, is preserved in the archives of Nuremberg. The celebrated astronomer Riccioli, though an Italian, yet does not seem willing to give his countryman the honour of this important discovery. In his *Geographia Reformata*, book iii. p. 90. he says, "Christopher Columbus never thought of an expedition to the West Indies until his arrival in the island of Madeira, where, amusing himself in forming and delineating geographical charts, he obtained information from Martin Bœhm, or, as the Spaniards say, from Alphonfus Sanches de Huelva, a pilot, who had chanced to fall in with the island afterwards called *Dominica*." And in another place: "Let Bœhm and Columbus have each their praise; they were both excellent navigators; but Columbus would never have thought of his expedition to America, had not Bœhm gone there before him. His name is not so much celebrated as that of Columbus, Americus, or Magellan, although he is superior to them all."

That Behem rendered some very important services to the crown of Portugal, is put beyond all controversy by the recompence bestowed on him by King John; of which the following account has been given to the public from the archives of Nuremberg. "In the year 1485, on the 18th of Feb. in Portugal, in the city of Allafavas, and in the church of St Salvador, after the mass, Martin Behem of Nuremberg was made a knight, by the hands of the most puissant Lord John II. king of Portugal, Algarve, Africa, and Guinea; and his chief squire was the king himself, who put the sword in his belt; and the Duke of Begia was his second squire, who put on his right spur; and his third squire was Count Christopher de Mela, the king's cousin, who put on his left spur; and his fourth squire was Count Martini Marbarinis, who put on his iron helmet; and the king himself gave him the blow on the shoulder, which was done in the presence of all the princes, lords, and knights of the kingdom; and he espoused the daughter of a great lord, in consideration of the important services he had performed; and he was made governor of the island of Fayal."

These marks of distinction, conferred on a stranger, could

Behem.

Behem.

could not be meant as a recompence for the discovery of the Azores, which was made twenty years before, but as a reward for the discovery of Congo, from whence the Chevalier Behem had brought gold and different kinds of precious wares. This discovery made much greater impression than that of a western world made at the same time, but which neither increased the wealth of the royal treasury, nor satisfied the avarice of the merchants.

In 1492 the Chevalier Behem, crowned with honours and riches, undertook a journey to Nuremberg, to visit his native country and his family. He there made a terrestrial globe, which is looked on as a masterpiece for that time, and which is still preserved in the library of that city. The outline of his discoveries may there be seen, under the name of western lands; and from their situation it cannot be doubted that they are the present coasts of Brazil, and the environs of the Straits of Magellan. This globe was made in the same year that Columbus set out on his expedition; therefore it is impossible that Behem could have profited by the works of that navigator, who besides went a much more northerly course.

After having performed several other interesting voyages, the Chevalier Behem died at Lisbon in July 1506, regretted by every one, but leaving behind him no other work than the globe and chart which we have just been speaking of. The globe is made from the writings of Ptolemy, Pliny, Strabo, and especially from the account of Mark Paul the Venetian, a celebrated traveller of the 13th century; and of John Mandeville, an Englishman, who, about the middle of the 14th century, published an account of a journey of 33 years in Africa and Asia. He has also added the important discoveries made by himself on the coasts of Africa and America.

From these circumstantial accounts, but very lately brought to light, there can be little doubt, we think, but that America was discovered by Martin Behem. Dr Robertson is indeed of a different opinion: but great as we willingly acknowledge his authority to be, we may differ from him without presumption, since he had it not in his power to consult the German documents to which we have appealed, and has himself advanced facts not easily to be reconciled to his own opinion. He allows that Behem was very intimate with Christopher Columbus; that he was the greatest geographer of his time, and scholar of the celebrated John Müller, or Regiomontanus; that he had discovered, in 1483, the kingdom of Congo, upon the coast of Africa; that he made a globe which Magellan made use of; that he drew a map at Nuremberg, containing the particulars of his discoveries; and that he placed in this chart land which is found to be in the latitude of Guiana. He adds indeed, without proof, that this land was a fabulous island; but if authentic records are to give place to bare assertion, there is an end of all historical evidence. If Behem took for an island the first land which he discovered, it was a mistake surely not so gross as to furnish grounds for questioning his veracity, or for withholding from him for ever that justice which has been so long delayed.

But this very delay will by some be thought a power-
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ful objection to the truth of Behem's claim to the discovery of America; for if it was really discovered by him, why did not he leave behind him some writing to confirm the discovery to himself? and why did not the court of Portugal, so jealous of the discovery of the new world, protest against the exclusive claim of the Spaniards?

To these objections we may reply, that, however plausible they may at first appear, they do not in the smallest degree invalidate the positive evidence which we have urged for the Chevalier Behem's being the real discoverer of the new world; for it would surely be very absurd to oppose the *difficulty of assigning motives* for certain actions performed at a remote period, to the *reality of other actions* for which we have the testimony of a cloud of contemporary witnesses. Supposing it were true, therefore, that Behem had left behind him no writing claiming to himself the discovery of any part of the continent of America, the only inference which could be drawn from his silence would be, either that he was a man of great modesty, or that his mind was intent only on the acquisition of knowledge to himself, without feeling the usual impulse to communicate that knowledge to others. But it is not true that he has left behind him no claim of this discovery to himself. The letters to which we have appealed, and which are preserved in the archives of Nuremberg, together with the globe and map, which he certainly made, furnish as complete a confirmation of his claim as could have been furnished by the most elegant account of his voyages.

For the silence of the Portuguese, many reasons might be assigned. The discoveries of Columbus were made so much farther north than those of Behem, that, in an age when geographical knowledge was so very limited, both Spaniards and Portuguese might very naturally believe that the country discovered by the former of these navigators had no connection with that discovered by the latter. At any rate, the Portuguese, whose discoveries proceeded from avarice, were satisfied with scraping together gold wherever they could find it; and finding it in Africa, they thought not of searching for it in a more distant region, till the success of the Spaniards shewed them their mistake.

One thing more is worthy of attention. The long stay of Columbus at Madeira makes his interview with Behem more than probable. It is impossible that he should have neglected seeing a man so interesting, and who could give him every kind of information for the execution of the plan which he had formed. The mariners who accompanied the Chevalier Behem might also have spread reports at Madeira and the Azores concerning the discovery of which they had been witnesses. What ought to confirm us in this is, that Mariana says himself (book xxvi. chap. iii.), that a certain vessel going to Africa, was thrown by a gale of wind upon certain unknown lands; and that the sailors at their return to Madeira had communicated to Christopher Columbus the circumstances of their voyage. All authors agree that this learned man had some information respecting the western shores; but they speak in a very vague manner. The expedition of the Chevalier Behem explains the mystery (B).

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BEREANS,

(B) For the greater part of this memoir we are indebted to M. Otto's paper on the discovery of America, published

Bereans.

BEREANS, in ancient church history, the inhabitants of Berea. They are highly commended in Scripture for their ready reception of the gospel, upon a fair and impartial examination of its agreement with the Old Testament prophecies. Sopater, a Berean, attended the apostle Paul to Asia. Acts xvii. 10—13. and xx. 4.

BEREANS, in modern church history, a sect of Protestant dissenters from the church of Scotland, who take their title from, and profess to follow, the example of the ancient Bereans, in building their system of faith and practice upon the Scriptures alone, without regard to any human authority whatever.

Doctrines.

The Bereans agree with the great majority of Christians, both Protestants and Catholics, respecting the doctrine of the Trinity, which they hold as a fundamental article of the Christian faith; and they also agree in a great measure with the *professed* principles of both our established churches respecting predestination and election, though they allege that these doctrines are not consistently taught in either church. But they differ from the majority of all sects of Christians in various other important particulars. Such as,

1. Respecting our knowledge of the Deity. Upon this subject, they say that the majority of professed Christians stumble at the very threshold of revelation; and, by admitting the doctrine of natural religion, natural conscience, natural notices, &c. not founded upon revelation, or derived from it by tradition, they give up the cause of Christianity at once to the infidels; who may justly argue, as Mr Paine in fact does in his *Age of Reason*, that there is no occasion for any revelation or word of God, if man can discover his nature and perfections from his works alone. But this, the Bereans argue, is beyond the natural powers of human reason; and therefore our knowledge of God is from revelation alone; and that without revelation man would never have entertained an idea of his existence.

2. With regard to faith in Christ, and assurance of salvation through his merits, they differ from almost all other sects whatsoever. These they reckon *inseparable*, or rather the *same*; because, they argue, God hath expressly declared, "He that believeth shall be saved;" and therefore it is not only absurd, but impious, and in a manner calling God a liar, for a man to say, "*I believe the Gospel, but have doubts* nevertheless of my own salvation." With regard to the various distinctions and definitions that have been given of different kinds of faith, they argue, that "there is nothing incomprehensible or obscure in the meaning of this word as used in Scripture; but that as faith, when applied to human testimony, signifies neither more nor less than the mere simple belief of that testimony as true, upon the authority of the testifier: so, when applied to the testimony of God, it signifies precisely the belief of his testimony, and resting upon his veracity alone, without any kind of collateral support from concurrence of any other evidence or testimony whatever." And they insist, that as this faith is the gift of God alone, so the person to whom it is given is as conscious of possessing it, as the being to whom God gives life is of being alive; and

Bereans.

therefore he entertains no doubts either of his faith or his consequent salvation through the merits of Christ, who died and rose again for that purpose. In a word, they argue, that the Gospel would not be what it is held forth to be, "glad tidings of great joy," if it did not bring full personal assurance of eternal salvation to the believer: which assurance, they insist, "is the present infallible privilege and portion of every individual believer of the Gospel." These definitions of faith, and its inseparable concomitant assurance, they prove by a variety of texts, which our room permits us not to quote.

3. Consistently with the above definition of faith, they say, that the sin against the Holy Ghost, which has alarmed and puzzled so many in all ages, is nothing else but *unbelief*; and that the expression, that "it shall not be forgiven, neither in *this world* nor that which is to come," means only, that a person dying in infidelity would not be forgiven, neither under the former dispensation by Moses (the then *present* dispensation, kingdom, or government of God), nor under the Gospel dispensation, which, in respect of the Mosaic, was a kind of future world or kingdom to come.

4. The Bereans interpret a great part of the Old Testament prophecies, and in particular the whole of the Psalms, excepting such as are merely historical or laudatory, to be typical or prophetic of Jesus Christ, his sufferings, atonement, mediation, and kingdom: and they esteem it a gross perversion of these Psalms and prophecies to apply them to the experiences of private Christians. In proof of this, they not only urge the words of the apostle, that "no prophecy is of any private interpretation," but they insist that the whole of the quotations from the ancient prophecies in the New Testament, and particularly those from the Psalms, are expressly applied to Christ. In this opinion many other classes of Protestants agree with them.

5. Of the absolute all-superintending sovereignty of the Almighty, the Bereans entertain the highest ideas, as well as of the uninterrupted exertion thereof over all works in heaven, earth, and hell, however unsearchable by his creatures. "A God without election (they argue), or choice in all his works, is a god without existence—a mere idol—a non-entity. And to deny God's election, purpose, and express will in all his works, is to make him inferior to ourselves." For farther particulars respecting the Berean doctrines, we must refer the reader to the works of Messrs Barclay, Nicol, Brookshank, &c.

The Bereans first assembled as a separate society of Christians in the city of Edinburgh in autumn 1773, and soon after in the parish of Fettercairn. The opponents of the Berean doctrines allege, that this new system of faith would never have been heard of, had not Mr Barclay, the founder of it, been disappointed of a settlement in the church of Scotland. A respectable clergyman of the established church has even hinted something to this purpose in Sir John Sinclair's *Statistical Account*, Vol. IX. p. 599. But the Bereans, in answer to this charge, appeal not only to Mr Barclay's doctrine,

Origins.

doctrines, uniformly preached in the church of Fettercairn, and many other places in that neighbourhood, for fourteen years before that benefice became vacant; but likewise to two different treatises, containing the same doctrines, published by him about ten or twelve years before that period. They admit, indeed, that, previous to May 1773, when the general assembly, by sustaining the king's presentation in favour of Mr Foote, excluded Mr Barclay from succeeding to the church of Fettercairn (notwithstanding the almost unanimous desire of the parishioners), the Bereans had not left the established church, or attempted to erect themselves into a distinct society; but they add, that this was by no means necessary on their part, until by the assembly's decision they were in danger of being not only deprived of his instructions, but of being scattered as sheep without a shepherd. And they add, that it was Mr Barclay's open and public avowal, both from the pulpit and the press, of those peculiar sentiments which now distinguish the Bereans, that was the first and principal, if not the only, cause of the opposition set on foot against his settlement in Fettercairn.

Having thus given a concise view of the origin and distinguishing doctrines of Bereanism, it only remains to mention a few particulars relative to the practice of the Bereans as a Christian society. Infant baptism they consider as a divine ordinance instituted in the room of circumcision; and they think it absurd to suppose that infants, who all agree are admissible to the kingdom of God in heaven, should nevertheless be incapable of being admitted into His visible church on earth. They commemorate the Lord's supper in general once a month; but as the words of the institution fix no particular period, they sometimes celebrate it oftener, and sometimes at more distant periods, as may suit their general convenience. In observing this ordinance, they follow the primitive apostolic plan, without any previous days of fasting or preparation; as they apprehend that such human institutions only tend to make an idol of the ordinance, and to lead people to entertain erroneous ideas of its superior solemnity and importance. Equal and universal holiness in all manner of conversation, they recommend at all times, as well as at the table of the Lord. They meet every Lord's day for the purpose of preaching, praying, and exhortation to love and good works. With regard to the admission and exclusion of members, their method is very simple. When any person, after hearing the Berean doctrines, professes his belief and assurance of the truths of the Gospel, and desires to be admitted into their communion, he is cheerfully received upon his profession, whatever may have been his former manner of life. But if such an one should afterwards draw back from his good profession or practice, they first admonish him; and if that has no effect, they leave him to himself. They do not think that they have any power to deliver up a backsliding brother to Satan. That text and other similar passages, such as, "Whatsoever ye shall bind on earth shall be bound in heaven," &c. they consider as restricted to the apostles and to the inspired testimony alone, and not to be extended to any church on earth, or any number of churches or of Christians, whether deciding by a majority of votes or by unanimous voices. Neither do they think themselves authorized, as a Christian church, to enquire into each others political opinions, any more

than to examine into each others notions of philosophy. They both recommend and practise, as Christian duties, submission to lawful authority; but they do not think that a man, by becoming a Christian, or joining their society, is under any obligation, by the rules of the Gospel, to renounce his rights of private judgment upon matters of public or private importance. Upon all such subjects they allow each other to think and act as each may see it his duty. And they require nothing more of their members than a uniform and steady profession of the apostolic faith, and a suitable walk and conversation. With regard to feet-washing and the like practices, which some other sects of Christians consider as duties, the Bereans are of opinion that they are by no means obligatory. They argue, that the example given by our Saviour of washing the feet of his disciples was not an institution of an ordinance, but merely a familiar instance, taken from the custom of the country, and adopted by our Lord on that occasion, to teach his followers that they ought at all times to be ready to perform even the meanest offices of kindness to each other.

It may not be improper to add to the above delineation of the principles and practice of the Bereans, that their doctrine has found converts in various places of Scotland, England, and America; and that they have congregations in Edinburgh, Glasgow, Paisley, Stirling, Crieff, Dundee, Arbroath, Montrose, Fettercairn, Aberdeen, and other towns in Scotland; as well as in London and various places in England; not to add Pennsylvania, the Carolinas, and other States in America.

The above account of the doctrines, origin, practice, and present state of this society, has been given to us by the founder himself.

BERKENHOUT (Dr John), was about the year 1730 born at Leeds in Yorkshire, and educated at the grammar-school in that town. His father, who was a merchant, and a native of Holland, intended him for trade; and with that view sent him at an early age to Germany, in order to learn foreign languages. After continuing a few years in that country, he made the tour of Europe in company with one or more English noblemen. On their return to Germany they visited Berlin, where Mr Berkenhout met with a near relation of his father's, the Baron de Bielsfeldt, a nobleman then in high estimation with Frederick the Great king of Prussia; distinguished as one of the founders of the Royal Academy of Sciences at Berlin, and universally known as a politician and a man of letters. With this relation our young traveller fixed his abode for some time; and, regardless of his original destination, became a cadet in a Prussian regiment of foot. He soon obtained an ensign's commission, and in the space of a few years was advanced to the rank of captain. He quitted the Prussian service on the declaration of war between England and France in 1756, and was honoured with the command of a company in the service of his native country. When peace was concluded in 1763, not choosing, we suppose, to lead a life of inactivity on half-pay, he went down to Edinburgh, and commenced student of physic. During his residence at that university, he published his *Clavis Anglica Linguae Botanica*; a book of great utility to all students of botany.

Having continued some years at Edinburgh, Mr Berkenhout

Berken-
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kenhout went to the university of Leyden, where he was admitted to the degree of M. D. in the year 1765. On this occasion he published a thesis, intitled, *Dissertatio medica inauguralis de Podagra*, which he dedicated to his relation Baron de Bielfeldt. Returning to England, Dr Berkenhout settled at Isleworth in Middlesex, and soon after published his *Pharmacopœia Medici*, the third edition of which was printed in 1782. In 1778 he was sent by government with the commissioners to America. Neither the commissioners nor their secretary were suffered by the congress to proceed further than New York. Dr Berkenhout, however, found means to penetrate as far as Philadelphia, where the congress was then assembled. He appears to have remained in that city for some time without molestation: but at last they began to suspect that he was sent by Lord North for the purpose of tampering with some of their leading members. The Doctor was immediately seized and committed to prison.

How long he remained a state prisoner, or by what means he obtained his liberty, we are not informed; but we find from the public prints, that he rejoined the commissioners at New York, and returned with them to England. For this temporary sacrifice of the emoluments of his profession, and in consideration of his having, in the service of his sovereign, committed himself to the mercy of a congress of enraged republicans, he obtained a pension.

Many years previous to this event, Dr Berkenhout had published his *Outlines of the Natural History of Great Britain and Ireland*, in three volumes 12mo; a work which established his reputation as a naturalist. In the year 1773 he wrote a pamphlet, intitled, *An Essay on the Bite of a Mad Dog, in which the Claim to Infallibility of the Principal Preservative Remedies against the Hydrophobia is examined*. This pamphlet is inscribed to Sir George Baker, and deserves to be universally read.

In the year following Dr Berkenhout published his *Symptomatology*; a book which is too universally known to require any recommendation.

At the beginning of the year 1788 he published a work, intitled, *First Lines of the Theory and Practice of Philosophical Chemistry*, which he dedicated to Mr Eden, now Lord Auckland, who had been one of the commissioners whom he accompanied to America.

These, we believe, are the Doctor's principal publications in the line of his profession; but he wrote on many other subjects with equal ability. His translation of *Count Tessin's Letters*, which was his first publication, and dedicated to the present king when prince of Wales, evinces his knowledge of the Swedish language, and shews him to have been a good poet. His *Essay on Ways and Means*, proves him to have been better acquainted with the system of taxation than most other men who have written on the subject. His biographical powers appear in his *Biographia Literaria*; and in all his works are sufficient proofs of his classical learning, and that the Italian, French, German, and Dutch languages, were familiar to him. He possessed likewise a very considerable degree of mathematical science, which he acquired in the course of his military studies; and to those more solid attainments he is said to have added no small skill in the fine arts of painting and music. This eminent man, who, for the variety and promptitude of

his knowledge, has been compared to the Admirable Crichton, died on the 3d of April 1791.

BERNOULLI (John), a celebrated mathematician, was born at Basil the 7th of August 1667. His father intended him for trade; but his own inclination was at first for the belles lettres, which, however, like his brother James, whose life is given in the Encyclopædia, he left for mathematics. He laboured with his brother to discover the method used by Leibnitz, in his essays on the differential calculus, and gave the first principles of the integral calculus. Our author, with Messrs Huygens and Leibnitz, is said to have been the first who gave the solution of the problem proposed by James Bernoulli, concerning the catenary, or curve formed by a chain suspended by its two extremities. But for more on this subject, see ARCH in this Supplement.

John Bernoulli had the degree of doctor of physic at Basil, and two years afterward was named professor of mathematics in the university of Groningen. It was here that he discovered the mercurial phosphorus, or luminous barometer; and where he resolved the problem proposed by his brother concerning isoperimetricals.

On the death of his brother James, the professor at Basil, our author returned to his native country, against the pressing invitations of the magistrates of Utrecht to come to that city, and of the university of Groningen, who wished to retain him. The Academic Senate of Basil soon appointed him to succeed his brother, without assembling competitors, and contrary to the established practice; an appointment which he held during his whole life.

In 1714 was published his treatise on the management of ships; and in 1730 his memoir on the elliptical figure of the planets gained the prize of the Academy of Sciences. The same Academy also divided the prize for their question concerning the inclination of the planetary orbits, between our author and his son Daniel. See BERNOULLI (Daniel), *Encycl.*

John Bernoulli was a member of most of the academies of Europe, and received as a foreign associate of that of Paris in 1699. After a long life spent in constant study and improvement of all the branches of the mathematics, he died full of honours, the 1st of January 1748, in the 81st year of his age. Of five sons which he had, three pursued the same sciences with himself. One of these died before him; the two others, Nicolas and Daniel, he lived to see become eminent, and much respected in the same sciences.

The writings of this great man were dispersed through the periodical memoirs of several academies, as well as in many separate treatises. And the whole of them were carefully collected and published at Lausanne and Geneva, 1742, in 4 vols 4to. He was of undoubted eminence; but even in science he was a hasty man, and certainly envious of the fame of Newton.

BETELGUESE, a fixed star of the first magnitude, in the right shoulder of Orion.

BEZOUT (Stephen), a celebrated French mathematician, member of the Academies of Sciences and the Marine, and examiner of the guards of the marine and of the elites of artillery, was born at Nemours the 31st of March 1730. In the course of his studies he met with some books of geometry, which gave him a taste for that science; and the Eloges of Fontenelle, shewed him the honours attendant on talents and the

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love of the sciences. His father in vain opposed the strong attachment of young Bezout to the mathematical sciences. April 8. 1758, he was named adjoint-mechanician in the French Academy of Sciences; having before that sent them two ingenious memoirs on the integral calculus, and given other proofs of his proficiency in mathematics. In 1763, he was named to the new office of examiner to the marine, and appointed to compose a system of mathematics for their use; and in 1768, on the death of M. Camus, he succeeded as examiner of the artillery elevés.

Bezout fixed his attention more particularly to the resolution of algebraic equations; and he first found out the solution of a particular class of equations of all degrees. This method, different from all former ones, was general for the cubic and biquadratic equations, and just became particular only at those of the 5th degree. Upon this work our author laboured from 1762 till 1779, when he published it. He composed two courses of mathematics; the one for the marine, the other for the artillery. The foundation of these two works was the same; the applications only being different, according to the two different objects: these courses have every where been held in great estimation. In his office of examiner he discharged the duties with great attention, care, and tenderness. A trait of his justice and zeal is remarkable in the following instance: During an examination which he held at Toulon, he was told that two of the pupils could not be present, being confined by the small-pox: he himself had never had that disease, and he was greatly afraid of it; but as he knew that if he did not see these two young men, it would much impede their improvement, he ventured to their bed-sides to examine them, and was happy to find them so deserving of the hazard into which he put himself for their benefit.

Mr Bezout lived in this employment for several years, beloved of his family and friends, and respected by all, enjoying the fruits and the credit of his labours. But the trouble and fatigues of his offices, with some personal chagrins, had reduced his strength and constitution; he was attacked by a malignant fever, of which he died Sept. 27. 1783, in the 54th year of his age, regretted by his family, his friends, the young students, and by all his acquaintance in general.

The books published by him were: 1. Course of Mathematics for the use of the Marine, with a Treatise on Navigation, 6 vols in 8vo, Paris, 1764. 2. Course of Mathematics for the Corps of Artillery, 4 vols in 8vo, 1770. 3. General Theory of Algebraic Equations, 1779.

His papers printed in the volumes of the Memoirs of the Academy of Sciences are: 1. On curves, whose rectification depends on a given quantity, in the volume for 1758. 2. On several classes of equations that admit of an algebraic solution, 1762. 3. First volume of a course of mathematics, 1764. 4. On certain equations, &c. 1764. 5. General resolution of all equations, 1765. 6. Second volume of a course of mathematics, 1765. 7. Third volume of the same, 1766. 8. Fourth volume of the same, 1767. 9. Intergration of differentials, &c. vol. 3. Sav. Etr. 10. Experiments on cold, 1777.

BINOMIAL, a quantity consisting of two terms or members, connected by either of the signs + and —. See ALGEBRA, def. 9. *Encycl.*

Impossible or Imaginary BINOMIAL, is a binomial which

has one of its terms an impossible or an imaginary quantity; as $a + \sqrt{-b}$.

BINOMIAL Curve, is a curve whose ordinate is expressed by a binomial quantity, as the curve whose ordinate is $x^a \times b + dx^c$. Stirling, Method. Diff. p. 58.

BINOMIAL Line, or *Surd*, is that in which at least one of the parts is a surd. Euclid, in the tenth book of his Elements, enumerates six kinds of binomial lines or surds, viz.

- First binomial $3 + \sqrt{5}$,
- 2d binomial $\sqrt{18} + 4$,
- 3d binomial $\sqrt{24} + \sqrt{18}$,
- 4th binomial $4 + \sqrt{3}$,
- 5th binomial $\sqrt{6} + 2$,
- 6th binomial $\sqrt{6} + \sqrt{2}$.

BINOMIAL Theorem. See ALGEBRA, Chap. VII. Sect. iii. (*Encycl.* Vol. I.); and *Infinite SERIES*, (Vol. XVII.) The reader who wishes for a fuller account of this famous theorem, may find it in Dr Hutton's Mathematical Tracts, Vol. I.

BIRD-CATCHING, is an art which, as it is practised by means of bird-lime, nets, decoys, &c. has been sufficiently explained in the Encyclopædia. But there is another method of catching birds alive, by means of a *fusée* or *musket*, which was invented by M. Vaillant during his travels in Africa, and is sufficiently ingenious to deserve a place here. It is as follows:

Put a smaller or larger quantity of powder into your fusée according as circumstances may require. Immediately above the powder place the end of a candle of sufficient thickness, ramming it well down; and then fill the barrel with water up to the mouth. When at a proper distance you fire a musket thus loaded at a bird, you will only *stun* it by watering and moistening its feathers; and if you be alert, you may easily lay hold of it before it have time to spoil its plumage by fluttering. Our author admits, that in his first attempts he often put too much powder, or too thick a piece of candle into his fusée, or fired at too short a distance; and when any one of these mistakes was committed, he generally found the candle entire in the animal's belly; but after a short apprenticeship he acquired sufficient skill to adjust matters so as that the water impelled by the powder went directly to the mark, whilst the tallow being lighter than the water fell short of it. If this method be indeed practicable (for not being sportsmen we have not made trial of it), it may on many occasions aid the researches of the ornithologist.

BIRDS-Nests, in cookery. See *Encycl.* and CAP and BURTON in this *Suppl.*

BLACK (Joseph, M. D.), who has been styled the father of pneumatic chemistry, and who, in that department of science, had certainly no superior, was born at Bourdeaux in France, in the year 1728. His father was a native of Ireland, but went to Bourdeaux to carry on the business of a wine-merchant; though with what success he carried it on we have not learned. Where young Black received his classical education we know not; but at an early period of life he was sent to the University of Glasgow, and strongly recommended to Dr Cullen, who advised him to study physic, and undertook, with that ardour which characterised his mind, to render him every service in his power.

At that period Cullen read lectures on chemistry in the College of Glasgow with great and deserved applause;

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Black.

Black.

plause; and Black becoming one of his favourite pupils, was allowed the free use of his laboratory, and assisted him in his experiments; by which means he acquired a decided taste for this branch of natural philosophy. In 1754 he took the degree of doctor of physic in the university of Edinburgh, where he had studied for some time; and the choice which he made in regard to the subject of his inaugural dissertation gave a proof of his attachment to chemical pursuits. It was *De humore acido a cibus orto et magnesia alba*. The principles of the doctrine which he brought forward in this thesis he afterwards fully explained in a paper read the next year before a society in Edinburgh, and published in the second volume of *Essays Physical and Literary*, 1756; containing experiments on magnesia alba, quick-lime, and alkaline substances. In this paper, by an ingenious and philosophical series of researches, he evidently proved the existence of an aerial fluid, which he called *fixed air*, the presence of which gave mildness, and its absence causticity, to alkalies and calcareous earths. This noble discovery certainly paved the way to all that important knowledge respecting aerial bodies which has done so much honour to the names of a Cavendish, a Priestley, and a Lavoisier, and which have made chemical philosophy assume an entirely new form.

In the year 1756, on the removal of Dr Cullen to Edinburgh, Dr Black became professor of medicine and lecturer on chemistry in the university of Glasgow. Next year he enriched the science of chemistry with the curious doctrine of *latent heat*, in which he explained, in what has been hitherto reckoned a clear and satisfactory manner, the connection of heat with fluidity, the phenomena of freezing and boiling, and the manner in which they affect the thermometer. These discoveries, the result of great natural sagacity and experimental skill, certainly laid the foundation of all those important facts relating to this part of chemistry which were afterwards brought to light by several of the most eminent philosophers of the present period, and would alone be sufficient to give celebrity to the name of Black. His reputation indeed was now raised so high, that a vacancy having taken place in the chemical chair of Edinburgh, by the removal of Dr Cullen, in 1765, to another department, Dr Black was looked up to as the only man capable of sustaining, in this branch of science, the superiority which that celebrated school of medicine had acquired in all others. He was therefore elected to succeed Cullen, and for many years discharged the duties of the office with universal approbation, being much admired for the care, perspicuity, and elegance, with which he communicated instruction in his lectures, and his neatness and accuracy in performing experiments. Very complete manuscript copies of his lectures were taken by many of his students, particularly in the early part of his teaching, when they contained a great deal of matter then little known to the chemical world; and these copies, read with avidity by the lovers of this science, have greatly contributed to secure to him the honour of those discoveries, and that original mode of reasoning, which he scarcely ever made public in any other form. His lectures have lately been revised by his friend Dr Robison of Edinburgh; and, enriched with many valuable notes by that genuine philosopher, are now in the press, and will speedily be published.

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After his election to the chemical chair, Dr Black published nothing but a paper on the Effect of Boiling upon Water, in disposing it to freeze more readily, printed in the sixty-fifth volume of the Philosophical Transactions for 1774; and an Analysis of the Water of some Hot Springs in Iceland, in the Philosophical Transactions of Edinburgh for 1791. The latter contains some observations, highly interesting to the chemist, on the formation of the siliceous stone deposited by these wonderful springs; and has long been considered as a model of neatness and accuracy in the analysis of mineral waters. Two of his letters on chemical subjects have been published by Crell and Lavoisier.

Dr Black was long a strenuous opposer of the new theories in chemistry; but he at length became an avowed convert to the principles of the French chemists, and did not hesitate to make amends by his applause for his former opposition. He never distinguished himself as a practical physician. His manners were simple, his temper cold and reserved, and his habits of life adapted to his own convenience. He was never married; and died suddenly, in his sixty-second year, on the 6th of December 1799, his health having been in a declining state for some time before. He was a member of the Royal Societies of London and Edinburgh, and of the Imperial Academy of Sciences at St Petersburg; and by the interest of Lavoisier he was chosen one of the eight foreign members of the Academy of Sciences of Paris, when that academy was Royal, and when a philosopher of Britain could be a member of it without incurring disgrace.

By those who knew Dr Black intimately, and are capable of forming an estimate of the powers of his mind, he is believed to have been capable of becoming in chemistry what Newton was in mechanical philosophy; but an unconquerable indolence, though it could not prevent him from doing his duty as professor, restrained him not only from employing, as he might have done, his admirable talents in enlarging the boundaries of science, but even from asserting his claim to discoveries which were certainly his. Of these we hope to have some account from his friend the editor of his lectures.

BLACKLOCK (Dr Thomas) deserves, on so many accounts, to have the principal incidents of his life recorded in this work, that to omit such an article from our list of biographical sketches would be unpardonable negligence. We cannot, however, propose to write of him any thing which has not been written before, by an author who has repeatedly appeared before the public, and on each appearance has gained possession of the public heart. We shall therefore content ourselves with inserting in this place a short abridgment of the elegant account of the life and writings of Dr Blacklock, which was prefixed to that edition of his works which was published in 1793; and if we thus lessen our own labour, we are conscious that we shall at the same time increase the pleasure of our readers.

Thomas Blacklock was in 1721 born at Anau, in the county of Dumfries in Scotland, but his parents were natives of the bordering county of Cumberland; so that, though a native of Scotland, his descent was English. His father was a bricklayer, and his mother the daughter of a considerable dealer in cattle. Both were respectable in their characters, and possessed, tho' moving

Blacklock. moving in an humble sphere, a considerable degree of knowledge and urbanity. Their son was not quite six months old when he lost his eye-sight in the small-pox, which rendered him as complete a stranger to the visible world as if he had been blind from the hour of his birth. It rendered him likewise incapable of learning any of the mechanical arts; and therefore his father kept him at home, and with the assistance of some friends fostered that inclination which, at a very early period, he shewed for books. This was done by reading to him first the simple sort of publications which are commonly put into the hands of children, and then several of our best authors, such as Milton, Spencer, Prior, Pope, and Addison. His companions, whom his early gentleness and kindness of disposition, as well as their compassion for his misfortune, strongly attached to him, were very assiduous in their good offices, in reading to instruct and amuse him. By their assistance he acquired some knowledge of the Latin tongue, but he never was at a grammar-school till at a more advanced period of life. Poetry was even then his favourite reading; and he found an enthusiastic delight in the works of the best English poets, and in those of his countryman Allan Ramsay. Even at an age so early as twelve he began to write poems, one of which is preserved in the collection that was published after his death, and is not perhaps inferior to any of the premature compositions of boys assisted by the best education, which are only recalled into notice by the future fame of their authors.

He had attained the age of nineteen when his father was killed by the accidental fall of a malt-kiln belonging to his son-in-law. This loss, heavy to any one at that early age, would have been, however, to a young man possessing the ordinary means of support, and the ordinary advantages of education, comparatively light; but to him—thus suddenly deprived of that support on which his youth had leaned—destitute almost of every resource which industry affords to those who have the blessings of sight—with a body feeble and delicate from nature, and a mind congenially susceptible—it was not surprising that this blow was doubly severe, and threw on his spirits that despondent gloom to which he then gave way in the following pathetic lines, and which sometimes overclouded them in the subsequent period of his life:

“ Dejecting prospect! soon the hapless hour
 “ May come; perhaps this moment it impends,
 “ Which drives me forth to penury and cold,
 “ Naked, and beat by all the storms of heav’n,
 “ Friendless and guideless to explore my way;
 “ Till on cold earth this poor unshelter’d head
 “ Reclining, vainly from the ruthless blast
 “ Respite I beg, and in the shock expire.”

He lived with his mother for about a year after his father’s death, and began to be distinguished as a young man of uncommon parts and genius. These were at that time unassisted by learning; the circumstances of his family affording him no better education than the smattering of Latin which his companions had taught him, and the perusal and recollection of the few English authors which they, or his father in the intervals of his professional labours, had read to him. Poetry, however, though it attains its highest perfection in a cultivated soil, grows perhaps as luxuriantly in a wild one. To

poetry, as we have before mentioned, he was devoted from his earliest days; and about this time several of his poetical productions began to be handed about, which considerably enlarged the circle of his friends and acquaintance. Some of his compositions being shewn to Dr Stevenson, an eminent physician of Edinburgh, who was accidentally at Dumfries on a professional visit, that gentleman formed the benevolent design of carrying him to the Scotch metropolis, and giving to his natural endowments the assistance of a classical education. He came to Edinburgh in the year 1741, and was enrolled a student of divinity in the university there, though at that time without any particular view of entering into the church. In that university he continued his studies under the patronage of Dr Stevenson till the year 1745, when he retired to Dumfries, and resided in the house of Mr M^r Murdo, who had married his sister, during the whole time of the civil war, which then raged in the country, and particularly disturbed the tranquillity of the metropolis. When peace was restored to the nation, he returned to the university, and pursued his studies for six years longer. During this last residence in Edinburgh, he obtained, among other literary acquaintance, that of the celebrated DAVID HUME, who attached himself warmly to Mr Blacklock’s interests, and was afterwards particularly useful to him in the publication of the 4th edition of his Poems, which came out by subscription in London in the year 1756. Previously to this, two editions in 8vo had been published at Edinburgh, the first in 1746, and the second in 1754.

In the course of his education at Edinburgh, he acquired a proficiency in the learned languages, and became more a master of the French tongue than was then common in that city. For this last acquisition he was chiefly indebted to the social intercourse to which he had the good fortune to be admitted in the house of Provost Alexander, who had married a native of France. At the university he attained a knowledge of the various branches of philosophy and theology, to which his course of study naturally led, and acquired at the same time a considerable fund of learning and information in those various departments of science and belles lettres, from which his want of sight did not absolutely preclude him.

In 1757, he began a course of study, with a view to give lectures in oratory to young gentlemen intended for the bar or the pulpit. On this occasion he wrote to Mr Hume, informed him of his plan, and requested his assistance in the prosecution of it. But Mr Hume doubting the probability of its success, he abandoned the project; and then, for the first time, adopted the decided intention of going into the church of Scotland. After applying closely for a considerable time to the study of theology, he passed the usual trials in the presbytery of Dumfries, and was by that presbytery licensed a preacher of the gospel in the year 1759. As a preacher he obtained high reputation, and was fond of composing sermons, of which he has left some volumes in manuscript, as also a Treatise on Morals.

The tenor of his occupations, as well as the bent of his mind and dispositions, during this period of his life, will appear in the following plain and unstudied account, contained in a letter from a gentleman, who was then his most intimate and constant companion, the Rev. Mr Jamieson.

Blacklock. Jameſon, formerly miniſter of the Epifcopal chapel at Dumfries, afterwards of the Engliſh congregation at Dantzic, and who lately reſided, and perhaps yet reſides, at Newcastle upon Tyne.

“His manner of life (ſays that gentleman) was ſo uniform, that the hiſtory of it during one day, or one week, is the hiſtory of it during the ſeven years that our perſonal intercourse laſted. Reading, muſic, walking, converſing, and diſputing on various topics, in theology, ethics, &c. employed almoſt every hour of our time. It was pleaſant to hear him engaged in a diſpute, for no man could keep his temper better than he always did on ſuch occaſions. I have known him frequently very warmly engaged for hours together, but never could obſerve one angry word to fall from him. Whatever his antagoniſt might ſay, he always kept his temper. ‘*Semper paratus et refellere ſine pertinacia, et refelli ſine iracundia.*’ He was, however, extremely ſenſible to what he thought ill uſage, and equally ſo whether it regarded himſelf or his friends. But his reſentment was always confined to a few ſatirical verſes, which were generally burnt ſoon after.

“I have frequently admired with what readineſs and rapidity he could ſometimes make verſes. I have known him dictate from thirty to forty verſes, and by no means bad ones, as faſt as I could write them; but the moment he was at a loſs for a rhyme or a verſe to his liking, he ſtopt altogether, and could very ſeldom be induced to finiſh what he had begun with ſo much ardour.”

This account ſufficiently marks that eager ſenſibility, chaſtened at the ſame time with uncommon gentleneſs of temper, which characteriſed Dr Blacklock, and which indeed it was impoſſible to be at all in his company without perceiving. In the ſcience of mind, this is that diviſion of it which perhaps one would peculiarly appropriate to poetry, at leaſt to all thoſe lighter ſpecies which rather depend on quickneſs of feeling, and the ready conception of pleaſing images, than on the happy arrangement of parts, or the ſkilful conſtruction of a whole, which are eſſential to the higher departments of the poetical art. The firſt kind of talent is like thoſe warm and light foils which produce their annual crops in ſuch abundance; the laſt, like that deeper and firmer mould on which the roots of eternal foreſts are fixed. Of the firſt we have ſeen many happy inſtances in that ſex which is ſuppoſed leſs capable of ſtudy or thought; from the laſt is drawn that maſculine ſublimity of genius which could build an Iliad or a Paradife Loſt.

Dr Blacklock could never dictate till he ſtood up; and as his blindneſs made walking about without aſſiſtance inconvenient or dangerous to him, he fell inſenſibly into a vibratory ſort of motion of his body, which increaſed as he warmed with his ſubject, and was pleaſed with the conceptions of his mind. This motion at laſt became habitual to him; and though he could ſometimes reſtrain it when on ceremony, or on any public appearance, ſuch as preaching, he felt a certain uneaſineſs from the effort, and always returned to it when he could without impropriety. This appearance he deſcribes in a ſhort poem, in which he gives a ludicrous picture of himſelf; a picture indeed, of which, though the outlines are true, the general effect is greatly overcharged. Though his features were hurt by the diſ-

eaſe which deprived him of ſight, there was a certain placid expreſſion in his countenance, which marked the benevolence of his heart, and was calculated to procure to him individual attachments and general regard.

In 1762 he married Miſs Sarah Johnſton, daughter of Mr Joſeph Johnſton ſurgeon in Dumfries; a connection which formed the great ſolace and bleſſing of his future life, and gave him, with all the tenderneſs of a wife, all the zealous care of a guardian and a friend. This event took place a few days before his being ordained miniſter of the town and pariſh of Kircudbright, in conſequence of a preſentation from the crown, obtained for him by the earl of Selkirk, a benevolent nobleman, whom Mr Blacklock’s ſituation and genius had intereſted in his behalf. But the inhabitants of the pariſh, whether from that violent averſion to patronage, which was then ſo univerſal in the ſouthern parts of Scotland, from ſome political diſputes which at that time ſubſiſted between them and his noble patron, or from thoſe prejudices which ſome of them might naturally enough entertain againſt a paſtor deprived of ſight, or perhaps from all theſe cauſes united, were ſo extremely diſinclined to receive him as their miniſter, that after a legal diſpute of nearly two years, it was thought expedient by his friends, as it had always been wiſhed by himſelf, to compromise the matter, by reſigning his right to the living, and accepting a moderate annuity in its ſtead. With this ſlender proviſion he removed in 1764 to Edinburgh; and to make up by his induſtry a more comfortable and decent ſubſiſtence, he adopted the plan of receiving a certain number of young gentlemen as boarders into his houſe, whoſe ſtudies in languages and philoſophy he might, if neceſſary, aſſiſt. In this ſituation he continued till the year 1787, when he found his time of life and ſtate of health required a degree of quiet and reſoſe, which induced him to diſcontinue the receiving of boarders. In 1767 the degree of doctor in divinity was conferred on him by the univerſity and Mariſchal college of Aberdeen.

In the occupation which he thus exerciſed for ſo many years of his life, no teacher was perhaps ever more agreeable to his pupils, nor maſter of a family to its inmates, than Dr Blacklock. The gentleneſs of his manners, the benignity of his diſpoſition, and that warm intereſt in the happineſs of others which led him ſo conſtantly to promote it, were qualities that could not fail to procure him the love and regard of the young people committed to his charge; while the ſociety, which eſteem and reſpect for his character and his genius often aſſembled at his houſe, afforded them an advantage rarely to be found in eſtabliſhments of a ſimilar kind.

In this mixed ſociety he appeared to forget the privation of ſight, and the melancholy which it might at other times produce in his mind. He entered, with the cheerful playfulneſs of a young man, into all the ſprightly narrative, the ſportful fancy, and the humorous jeſt that roſe around him. Next to converſation, muſic was perhaps the ſource of his greateſt delight; for he not only reliſhed it highly, but was himſelf a tolerable performer on ſeveral inſtruments, particularly the flute. He generally carried in his pocket a ſmall *flageolet*, on which he played his favourite tunes; and was not diſpleaſed when aſked in company to play or to ſing them; a natural feeling for a blind man, who thus adds a ſcene to the drama of his ſociety.

Blacklock.

Of the happiness of others, however, we are incompetent judges. Companionship and sympathy bring forth those gay colours of mirth and cheerfulness which they put on for a while, to cover perhaps that sadness which we have no opportunity of witnessing. Of a blind man's condition we are particularly liable to form a mistaken estimate; we give him credit for all those gleams of delight which society affords him, without placing to their full account those dreary moments of darkness and solitude to which the suspension of that society condemns him. Dr Blacklock had from nature a constitution delicate and nervous, and his mind, as is almost always the case, was in a great degree subject to the indisposition of his body. He frequently complained of a lowness and depression of spirits, which neither the attentions of his friends, nor the unceasing care of a most affectionate wife, were able entirely to remove. The imagination we are so apt to envy and admire serves but to irritate this disorder of the mind; and that fancy in whose creation we so much delight, can draw, from sources unknown to common men, subjects of disgust, inquietude, and affliction. Some of his later poems express a chagrin, though not of an ungentle sort, at the supposed failure of his imaginative powers; or at the fastidiousness of modern times, which he despaired to please.

“Such were his efforts, such his cold reward,
 “Whom once thy partial tongue pronounc'd a bard;
 “Excursive, on the gentle gales of spring,
 “He rov'd, whilst favour imp'd his timid wing;
 “Exhausted genius now no more inspires,
 “But mourns abortive hopes, and faded fires;
 “The short-liv'd wreath, which once his temples grac'd,
 “Fades at the sickly breath of squeamish taste;
 “Whilst darker days his fainting flames immure
 “In cheerless gloom and winter premature.”

These lines are, however, no proof of “exhausted genius,” or “faded fires.” “Abortive hopes,” indeed, must be the lot of all who, like Dr Blacklock, reach the period of old age. In early youth the heart of every one is a poet; it creates a scene of imagined happiness and delusive hopes; it clothes the world in the bright colours of its own fancy; it refines what is coarse, it exalts what is mean; it sees nothing but disinterestedness in friendship; it promises eternal fidelity in love. Even on the distresses of its situation it can throw a certain romantic shade of melancholy that leaves a man sad, but does not make him unhappy. But at a more advanced age, “the fairy visions fade,” and he suffers most deeply who has indulged them the most.

About the time that these verses were written, Dr Blacklock was, for the first time, afflicted with what to him must have been peculiarly distressful. He became occasionally subject to deafness, which, though he seldom felt it in any great degree, was sufficient, in his situation, to whom the sense of hearing was almost the only channel of communication with the external world, to cause very lively uneasiness. Amidst these indispositions of body, however, and inquietudes of mind, the gentleness of his temper never forsook him, and he felt all that resignation and confidence in the Supreme Being which his earliest and his latest life equally acknowledged. In summer 1791 he was seized with a feverish disorder, which at first seemed of a slight, and never rose to a very violent kind; but a frame so little robust as

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his was not able to resist it, and after about a week's illness it carried him off on the 7th day of July 1791. His wife survives him, to feel, amidst the heavy affliction of his loss, that melancholy consolation which is derived from the remembrance of his virtues.

The writings of Dr Blacklock consisted principally of poems, which were published in 4to in the year 1793; and to that edition was added, *An Essay on the Education of the Blind, translated from the French of M. Hauy*. But besides his avowed works, we have reason to believe that he was the author of many articles in the second edition of the *Encyclopædia Britannica*, though we cannot say with certainty what those articles were. If our memory does not deceive us, we have been informed that the preface to that edition was furnished by him; and we have elsewhere attributed to him, on the best authority, the article **BLIND**, and the *Notes* to the article **MUSIC**: but he undoubtedly contributed much more to the work, and was one of the principal guides of the proprietors.

BLAIR (Dr Hugh), was born in Edinburgh, on the 7th day of April 1718. His father, John Blair, a respectable merchant in that city, was a descendant of the ancient family of Blair in Airshire, and grandson of the famous Mr Robert Blair minister of St Andrew's, chaplain to Charles I. and one of the most zealous and distinguished clergymen of the period in which he lived. This worthy man, though firmly attached to the cause of freedom, and to the Presbyterian form of church government, and though actively engaged in all the measures adopted for their support; yet, by his steady, temperate conduct, commanded the respect even of his opponents. In preference to all the other ecclesiastical leaders of the covenanting party, he was selected by the king himself to fill an office which, from the circumstances of the time, gave frequent access to the royal person; “because (said his majesty) that man is pious, prudent, learned, and of a meek and moderate calm temper.” His talents seem to have descended as an inheritance to his posterity. For of the two sons who survived him, David, the eldest, was a clergyman of eminence in Edinburgh, father to Mr Robert Blair minister of Athelstonford, the celebrated author of the poem intitled *The Grave*; and grandfather to his majesty's solicitor general for Scotland, whose masculine eloquence and profound knowledge of law have, in the public estimation, placed him indisputably at the head of the Scottish bar. From his youngest son Hugh, who engaged in business as a merchant, and had the honour to fill a high station in the magistracy of Edinburgh, sprung the learned clergyman who is the subject of this narrative.

The views of Dr Blair, from his earliest youth, were turned towards the church; and his education received a suitable direction. After the usual grammatical course at school, he entered the humanity class in the university of Edinburgh in October 1730, and spent eleven years at that celebrated seminary, assiduously employed in the literary and scientific studies prescribed by the church of Scotland to all who are to become candidates for her licence to preach the gospel. During this important period, he was distinguished among his companions both for diligence and proficiency; and obtained from the professors under whom he studied repeated testimonies of approbation. One of them de-

Blair.

Blair.

merits to be mentioned particularly, because, in his own opinion, it determined the bent of his genius towards polite literature. An essay *Περί του καλου*, or, *On the Beautiful*, written by him when a student of logic in the usual course of academical exercises, had the good fortune to attract the notice of professor Stevenson, and, with circumstances honourable to the author, was appointed to be read in public at the conclusion of the term or session. This mark of distinction made a deep impression on his mind; and the essay which merited it he ever after recollected with partial affection, and preserved to the day of his death as the first earnest of his fame.

At this time Dr Blair commenced a method of study which contributed much to the accuracy and extent of his knowledge, and which he continued to practise occasionally even after his reputation was fully established. It consisted in making abstracts of the most important works which he read, and in digesting them according to the train of his own thoughts. History, in particular, he resolved to study in this manner; and, in concert with some of his youthful associates, he constructed a very comprehensive scheme of chronological tables, for receiving into its proper place every important fact that should occur. The scheme devised by this young student for his own private use was afterwards improved, filled up, and given to the public by his learned friend Dr John Blair, prebendary of Westminster, in his valuable work, "The Chronology and History of the World."

In the year 1739, Dr Blair took his degree of A. M. On that occasion he printed and defended a thesis, *De Fundamentis et Obligatione Legis Naturæ*, which contains a short but masterly discussion of this important subject, and exhibits in elegant Latin an outline of the moral principles which have been since more fully unfolded and illustrated in his Sermons.

The university of Edinburgh, about this period, numbered among her pupils many young men who were soon to make a distinguished figure in the civil, the ecclesiastical, and the literary history of their country. With most of them Dr Blair entered into habits of intimate connection, which no future competition or jealousy occurred to interrupt, which held them united through life in their views of public good, and which had the most beneficial influence on their own improvement, on the progress of elegance and taste among their contemporaries, and on the general interests of the community to which they belonged.

On the completion of his academical course, he underwent the customary trials before the presbytery of Edinburgh, and received from that venerable body a licence to preach the Gospel on the 21st of October 1741. His public life now commenced with very favourable prospects. The reputation which he brought from the university was fully justified by his first appearances in the pulpit; and, in a few months, the fame of his eloquence procured for him a presentation to the parish of Colestie in Fife, where he was ordained to the office of the holy ministry on the 23d of September 1742. But he was not permitted to remain long in this rural retreat. A vacancy in the second charge of the Canon-gate, a suburb of Edinburgh, furnished to his friends an opportunity of recalling him to a station more suited to his talents. And, though one of the most popular and eloquent clergymen in the church was placed in com-

petition with him, a great majority of the electors decided in favour of this young orator, and restored him in July 1743 to the bounds of his native city.

In this station Dr Blair continued eleven years, discharging with great fidelity and success the various duties of the pastoral office. His discourses from the pulpit in particular attracted universal admiration. They were composed with uncommon care; and, occupying a middle place between the dry metaphysical discussion of one class of preachers, and the loose incoherent declamation of another, they blended together, in the happiest manner, the light of argument with the warmth of exhortation, and exhibited captivating specimens of what had hitherto been rarely heard in Scotland, the polished, well-compacted, and regular didactic oration.

In consequence of a call from the town-council and general-session of Edinburgh, he was translated from the Canon-gate to Lady Yester's, one of the city churches, on the 11th of October 1754: and on the 15th day of June 1758, he was promoted to the High Church of Edinburgh, the most important ecclesiastical charge in Scotland. To this charge he was raised at the request of the Lords of Council and Session, and of the other distinguished official characters who have their seats in that church. And the uniform prudence, ability, and success, which, for a period of more than forty years, accompanied all his ministerial labours in that conspicuous and difficult station, sufficiently evince the wisdom of their choice.

Hitherto his attention seems to have been devoted almost exclusively to the attainment of professional excellence, and to the regular discharge of his parochial duties. No production of his pen had yet been given to the world by himself, except two sermons preached on particular occasions; some translations, in verse, of passages of Scripture for the psalmody of the church; and a few articles in the Edinburgh Review; a publication begun in 1755, and conducted for a short time by some of the ablest men in the kingdom. But standing as he now did at the head of his profession, and released by the labour of former years from the drudgery of weekly preparation for the pulpit, he began to think seriously on a plan for teaching to others that art which had contributed so much to the establishment of his own fame. With this view, he communicated to his friends a scheme of lectures on composition; and having obtained the approbation of the university, he began to read them in the college on the 11th of December 1759. To this undertaking he brought all the qualifications requisite for executing it well; and along with them a weight of reputation, which could not fail to give effect to the lessons he should deliver. For, besides the testimony given to his talents by his successive promotions in the church, the university of St Andrew's, moved chiefly by the merit of his eloquence, had in June 1757 conferred on him the degree of D. D. a literary honour which at that time was very rare in Scotland. Accordingly his first course of lectures was well attended, and received with great applause. The patrons of the university, convinced that they would form a valuable addition to the system of education, agreed in the following summer to institute a rhetorical class, under his direction, as a permanent part of their academical establishment: and on the 7th of April 1762, his Majesty was graciously pleased "to erect and endow a

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Blair. professorship of rhetoric and belles lettres in the university of Edinburgh; and to appoint Dr Blair, in consideration of his approved qualifications, regius professor thereof, with a salary of L.70." The lectures which he read as professor of rhetoric, he published in 1783, when he retired from the labours of the office; and the general voice of the public has pronounced them to be a most judicious, elegant, and comprehensive system of rules for forming the style and cultivating the taste of youth.

About the time in which he was occupied in laying the foundations of this useful institution, he had an opportunity of conferring another important obligation on the literary world, by the part which he acted in rescuing from oblivion the poems of Ossian. It was by the solicitation of Dr Blair and Mr John Home, that Mr Macpherson was induced to publish his *Fragments of Ancient Poetry*; and their patronage was of essential service in procuring the subscription which enabled him to undertake his tour through the Highlands for collecting the materials of Fingal, and of those other delightful productions which bear the name of Ossian. To these productions Dr Blair applied the test of genuine criticism; and soon after their publication gave an estimate of their merits in a *Dissertation*, which, for beauty of language, delicacy of taste, and acuteness of critical investigation, has few parallels. It was printed in 1763, and spread the reputation of its author throughout Europe.

The great objects of his literary ambition being now attained, his talents were for many years consecrated solely to the important and peculiar employments of his station. It was not till the year 1777 that he could be induced to favour the world with a volume of the Sermons which had so long furnished instruction and delight to his own congregation. But this volume being well received, the public approbation encouraged him to proceed: four other volumes followed at different intervals, the last of which was published after his death; and all of them experienced a degree of success of which few publications can boast. They circulated rapidly and widely wherever the English tongue extends; they were soon translated into almost all the languages of Europe; and his present Majesty, with that wise attention to the interests of religion and literature which distinguishes his reign, was graciously pleased to judge them worthy of a public reward. By a royal mandate to the Exchequer in Scotland, dated July 25th 1780, a pension of L.200 a-year was conferred on their author, which continued unaltered till his death.

In that department of his professional duty which regarded the government of the church, Dr Blair was steadily attached to the cause of moderation. From diffidence, and perhaps from a certain degree of inaptitude for extemporary speaking, he took a less public part in the contests of ecclesiastical politics than some of his contemporaries; and, from the same causes, he never would consent to become moderator of the General Assembly of the Church of Scotland. But his influence among his brethren was extensive: his opinion, guided by that sound uprightness of judgment, which formed the predominant feature of his intellectual character, had been always held in high respect by the friends with whom he acted; and, for many of the last

years of his life, it was received by them almost as a law. The great leading principle in which they cordially concurred with him, and which directed all their measures, was to preserve the church, on the one side, from a slavish, corrupting dependance on the civil power; and, on the other, from a greater infusion of democratical influence than is compatible with good order, and the established constitution of the country.

The reputation which he acquired in the discharge of his public duties, was well sustained by the great respectability of his private character. Deriving from family associations a strong sense of clerical decorum, feeling on his heart deep impressions of religious and moral obligation, and guided in his intercourse with the world by the same correct and delicate taste which appeared in his writings, he was eminently distinguished through life by the prudence, purity, and dignified propriety of his conduct. His mind, by constitution and culture, was admirably formed for enjoying happiness. Well balanced in itself by the nice proportion and adjustment of its faculties, it did not incline him to any of those eccentricities, either of opinion or of action, which are too often the lot of genius:—free from all tincture of envy, it delighted cordially in the prosperity and fame of his companions: sensible to the estimation in which he himself was held, it disposed him to dwell at times on the thought of his success with a satisfaction which he did not affect to conceal: inaccessible alike to gloomy and to peevish impressions, it was always master of its own movements, and ready, in an uncommon degree, to take an active and pleasing interest in every thing, whether important or trifling, that happened to become for the moment the object of his attention. This habit of mind, tempered with the most unsuspecting simplicity, and united to eminent talents and inflexible integrity, while it secured to the last his own relish of life, was wonderfully calculated to endear him to his friends, and to render him an invaluable member of any society to which he belonged. Accordingly there have been few men more universally respected by those who knew him, more sincerely esteemed in the circle of his acquaintance, or more tenderly beloved by those who enjoyed the blessing of his private and domestic connection.

In April 1748, he married his cousin Katharine Bannatine, daughter of the Rev. James Bannatine, one of the ministers of Edinburgh. By her he had a son who died in infancy, and a daughter who lived to her twenty-first year, the pride of her parents, and adorned with all the accomplishments that became her age and sex. Mrs Blair herself, a woman of great good sense and spirit, was also taken from him a few years before his death, after she had shared with the tenderest affection in all his fortunes, and contributed near half a century to his happiness and comfort.

Dr Blair had been naturally of a feeble constitution of body; but as he grew up his constitution acquired greater firmness and vigour. Though liable to occasional attacks from some of the sharpest and most painful diseases that afflict the human frame, he enjoyed a general state of good health; and, through habitual cheerfulness, temperance, and care, survived the usual term of human life.—For some years he had felt himself unequal to the fatigue of instructing his very large congregation from the pulpit; and, under the impression

Blair,
Bleaching.

which this feeling produced, he has been heard at times to say with a sigh, "that he was left almost the last of his contemporaries." Yet he continued to the end in the regular discharge of all his other official duties, and particularly in giving advice to the afflicted, who, from different quarters of the kingdom, solicited his correspondence. His last summer was devoted to the preparation of the last volume of his sermons; and, in the course of it, he exhibited a vigour of understanding and capacity of exertion equal to that of his best days. He began the winter pleased with himself on account of the completion of this work; and his friends were flattered with the hope that he might live to enjoy the accession of emolument and fame which he expected it would bring. But the seeds of a mortal disease were lurking unperceived within him. On the 24th of December 1800, he complained of a pain in his bowels, which, during that and the following day, gave him but little uneasiness; and he received as usual the visits of his friends. On the afternoon of the 26th, the symptoms became violent and alarming:—he felt that he was approaching the end of his appointed course: and retaining to the last moment the full possession of his mental faculties, he expired on the morning of the 27th, with the composure and hope which become a Christian pastor.

The lamentation for his death was universal and deep through the city which he had so long instructed and adorned. Its magistrates, participating in the general grief, appointed his church to be put in mourning; and his colleague in it, Dr Finlayson, from whom this account of his life is borrowed*, preached his funeral sermon, in which his character is drawn in a masterly manner, though with the almost unavoidable partiality of friendship.

* Blair's
Sermons,
vol. v.

If we, who know Dr Blair only in his writings, might presume to estimate his intellectual character, we should say that he possessed a sound judgment rather than what could be called a vigorous mind; that he had more taste than genius; and that he taught successfully, as far as it can be taught, *the art of poetry*, though he could not himself have been a poet. His moral character was amiable and respectable, though he seems, even from a hint dropt by his biographer, to have been in a slight degree tinctured with vanity. But this was surely a venial weakness; for where is the head that would be wholly unaffected by the fumes of incense burnt before it for fifty years?

BLEACHING. Since the article *Bleaching* in the Encyclopædia was written, very great improvements have been introduced into the art. Of these improvements we shall proceed to give an account.

Discovery
of the oxy-
muriatic
acid.

Mr Scheele of Sweden discovered the oxy-muriatic acid, or dephlogisticated muriatic acid, as he called it, about the year 1774, and soon after observed its effects on vegetable colours. His method of procuring it was as follows: In a sand-bath is to be placed a glass retort, in which muriatic acid has been poured upon manganese; to this small receivers are to be adapted capable of containing about twelve ounces each, into which is to be poured about two drachms of water, without any other lute than a slip of blotting-paper about the neck of the retort. In about a quarter of an hour a yellow air is perceived in the receiver, which is to be taken off. If the paper has been properly applied, the

air rushes out forcibly; the receiver must be quickly stopped, and another applied. Thus many receivers may be filled with the dephlogisticated muriatic acid; but it is necessary to place the retort in such a manner that the drops which rise into its neck may be able to fall back. The water serves to retain the vapours of the acid. "I use (says he) many receivers, that I may not be obliged to repeat a similar distillation for every experiment. It is not proper to employ large ones, because every time they are opened a great part of the acid is dissipated in the air. What I submitted to examination with this dephlogisticated muriatic acid was placed in the neck of the receiver, which I had stopped. The cork was turned yellow as by aquafortis. Paper tinged with turnsol became almost white; all red, blue, and yellow flowers, as also green plants, turned yellow in a short time, and the water in the receiver was changed into pure but weak muriatic acid. Neither alkalis nor acids were able to restore the colours of the flowers, or of the plants."

Bleaching

M. Berthollet, in 1785, proved that this acid was composed of muriatic acid combined with oxygen; and that when it had deprived vegetable matters of their colour, it was reduced to the state of common muriatic acid; that is, it had lost the oxygen with which it was united. This oxygen had combined with the colouring particles of the vegetable matter, and had rendered them colourless. After making these observations, it occurred to him that the oxy-muriatic acid might produce the same effect upon those particles which give colour to thread and cloth, and which it is the object of bleaching to destroy. "At first (says he) I made use of water highly impregnated with this acid; and I renewed it when it was exhausted, until the thread or cloth appeared white; but I soon perceived that they were considerably weakened, and that they were entirely losing their solidity. I then weakened the liquor a little, and I succeeded in bleaching cloth without damaging it. But it speedily became yellow by keeping, especially if it was warmed, or passed through an alkaline ley. I reflected upon the circumstances of common bleaching, and I endeavoured to imitate its process, because I thought the oxygenated muriatic acid might act in the same manner as the exposition of the cloth in the meadows, which alone does not suffice, but which appears only to dispose the colouring parts of the cloth to be dissolved by the alkali of the ley. I examined dew, not only that which falls from the atmosphere, but also that which comes from the nocturnal transpiration of plants; and I observed that both of them were impregnated with oxygen, sufficiently to destroy the colour of paper slightly tinged with turnsol.

Its applica-
tion to
bleaching.

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Chim. II.
158.

"I therefore employed leys, and the action of oxygenated muriatic acid, alternately, and I then obtained a permanent white; and as, at the finishing of the common bleaching, the cloth is passed through four milk, or through sulphuric acid diluted with a very large quantity of water, I also tried passing the cloth through a very dilute solution of sulphuric acid, and I observed that the white was thereby rendered more clear. As soon as I made use of the leys intermediately, I found that it was not necessary to employ a concentrated liquor, or to let the cloth, at every immersion, remain long therein: by this I avoided two inconveniences, which would have rendered this process impossible to be

be

Bleaching. be practised in the large way. The first is the suffocating odour of the liquor, which it would be very inconvenient, and even dangerous, to respire for any length of time, and which has discouraged many persons who tried to use it; the second is, the danger of weakening the cloth. I now also left off mixing any alkali with the oxygenated muriatic acid, as I had practised in the greatest part of my first trials.

"This is nearly the state in which my experiments were, when I made some trials in the presence of the celebrated Mr Watt. A single view sufficed for a philosopher whose genius has been exercised so long upon the arts. In a short time Mr Watt wrote to me from England, that even in the first operation he had bleached five hundred pieces of cloth at Mr Grigor's, who has a large bleaching-ground at Glasgow, and who continues to make use of the new process. In the meantime M. Bonjour, who had hitherto assisted me in my experiments, and who joins great sagacity to a most extended knowledge of chemistry, associated himself with Mr Constant, at Valenciennes, in order to form an establishment in that city."

M. Caillau made a great number of experiments at Paris respecting this new mode of bleaching; but the greatest part of these experiments was made upon cotton, which is more easy to bleach, and does not require leys so often or so strong as flax or hemp. He also went to St Quentin, to perform the operation upon the cloth of that country; but he found that all the cloths, which he had bleached to the satisfaction of the manufacturers, became again of a reddish colour when they were exposed to a common ley, or even when they were left for some time in a warehouse. Several similar complaints were made by other persons; and M. Berthollet himself had observed the same thing in his own experiments. M. Bonjour, however, and M. Welter, affirmed that the cloth which they had bleached preserved its colour perfectly. M. Berthollet soon found, that the imperfection in his bleaching was owing to the manner in which he had used the leys. "I had contented myself (says he), in those trials on small pieces which I made in my laboratory, to pour the hot alkaline solution into a vessel where I placed the pieces: it there became cool very rapidly, and therefore did not act with sufficient power; but when I let these pieces remain in the liquor, which I kept nearly in a boiling heat during the space of two or three hours, they were then no longer subject to the above mentioned defects: it was therefore merely the weakness of the leys which had occasioned the accidents which were experienced by Messrs Caillau, Décroisille, and myself. It is necessary that the colour of the cloth should not be changed by the last ley, and this is the surest mark that the bleaching is finished; nevertheless, after this last action of the ley, it is proper to put the cloth, for a few moments, in the bleaching liquor.

"After this last immersion, it is necessary to plunge the cloth in four milk, or in water acidulated with sulphuric acid. I do not know the most convenient proportion of sulphuric acid; but it appeared to me that we might successfully, and without danger, make use of one part, in weight, of this acid to fifty of water. We must keep the cloths during about half an hour in this liquor warmed; after which it is proper to squeeze them well, and plunge them directly into common wa-

Bleaching. ter; for if the evaporation should take place, the sulphuric acid, becoming thereby concentrated, would corrode them. The cloths being then well washed, require only to be dried and dressed in the ordinary manner, according to their different sorts.

"It is of the utmost importance to take care that the water is not too strongly impregnated with the sulphuric acid.

"The bleaching of cotton cloth is much easier and shorter; two leys, or at most three, and as many immersions in the bleaching liquor, are sufficient for them. As they are bleached so easily, it is advantageous, when there are flaxen, hempen, and cotton cloths, to be bleached, to reserve for the cotton the liquors which have been previously weakened by the cloths of flax or hemp; for it is economical to exhaust the liquors as much as possible, and those which are considerably weakened still suffice for the cotton, although they have scarcely any action upon hemp or flax.

"Thread, in the common way of bleaching, is attended with a far greater number of difficulties than cloth; because of the immense number of surfaces which it is necessary to present successively to the action of the atmosphere. Some part of these difficulties occur in bleaching with the oxygenated muriatic acid; nevertheless, in the end, it is more advantageous with respect to thread than with respect to cloth. M. Welter has formed at Lille, with two partners, an establishment for bleaching thread, with great success, and he has already begun some others. He has found that ten or twelve leys, and as many immersions, are required for some sorts of thread; and, that the thread may be surrounded with the liquor, it is necessary to place it, quite loosely, in a basket, which permits the liquor to penetrate to all its surfaces; when the liquor is much weakened, it is still fit to be used for the bleaching of cotton.

"I had, in the beginning of my experiments, tried whether the vapour would not be preferable to the oxygenated muriatic acid in a liquid state, and I observed that it bleached with greater quickness; but, whatever precautions I employed, it appeared to me that a considerable loss of it took place; that those parts of the cloths which were the most exposed to it were subject to be weakened; and that it was more difficult to obtain an equal whiteness throughout.

"To prevent all the accidents which may result from the liquor acting with too great power, it is important to have a means of measuring its force. M. Décroisille thought of using, for that purpose, a solution of indigo in sulphuric acid. He takes one part of indigo, reduced into fine powder, and eighteen parts of concentrated sulphuric acid; this mixture is put into a matras, which is kept, during some hours, in a water-bath; when the solution is finished, it is diluted with a thousand parts of water. To try the power of the oxygenated muriatic acid, one measure of this solution is put into a graduated glass tube, and some of the liquor is gradually added to it, until the colour of the indigo is destroyed. We must first determine how many measures of a liquor, the goodness of which has been ascertained by experiments made upon cloth, are necessary to destroy the colour of one measure of the solution of indigo, and this number will serve to estimate the respective strength of all the liquors which it may be necessary.

Bleaching. necessary to compare with it. Mr Watt employs, in the same manner, a solution of cochineal."

³ Method of procuring the acid for bleaching. M. Berthollet recommended the following method of procuring the oxy-muriatic acid: "If we have good oxide of manganese, formed in small crystals, and containing but little extraneous matter, the proportions of the substances to be submitted to distillation are the following: Six ounces of calx of manganese reduced to powder; one pound of common salt, also reduced to powder; twelve ounces of concentrated sulphuric acid, or oil of vitriol; from ten to twelve ounces of water.

"When these materials are prepared, we must carefully mix the oxide of manganese with the common salt, and introduce the mixture into the distilling vessel placed upon a sand bath: we must then pour upon it the sulphuric acid, previously diluted (and of which the heat occasioned by its mixture with water is dissipated), and immediately apply to the mouth of the matras the tube which is to conduct the gas into the intermediate vessel.—It must not be forgot, that in this operation the lutes require particular attention.

"The size of the vessels should be such, that the distilling matras may be about one-third empty; and, for the quantity above mentioned, the tub should hold 100 quarts of water; there should also be an empty space of about 10 quarts, in order that when the gas lodges itself in the cavities intended to receive it, the water may have a free space to rise in.

"Before the commencement of the operation, the pneumatic tub must be filled with water. The mixture being made, the gas, which very soon begins to disengage itself, drives out the atmospheric air which is in the apparatus; when it is judged that the atmospheric air has passed into the cavities, it is to be drawn off by means of a bent tube, which is to be introduced successively under each cavity: to drive out the water which has entered into the tube, this last is to be forcibly blown into. The operation is then suffered to go on without fire until it is perceived that the bubbles come over but slowly: then a little fire is to be applied, which is not to be hastily increased at the beginning, but may be gradually augmented, so that at the end of the operation the matter may be brought to a boiling state. It is known to be nearly finished when the tube by which the gas is disengaged, and the intermediate vessel, become hot. When the gas is disengaged only in a small quantity, the fire may be withdrawn; and when the distilling vessel retains but a gentle warmth, it is to be unluted, and warm water is to be poured upon the residue, that it may remain in solution, and thereby be more easily poured out.

"The operation is longer or shorter according to the quantity of materials: with that above mentioned, it should last five or six hours; it is proper not to hasten it, that a larger quantity of gas may be drawn off. A single person is able to manage several distillations at the same time; to each of which may be given much larger quantities of materials than those which have been pointed out.

"The intermediate vessel by degrees becomes filled with a liquor, which is pure, though weak, muriatic acid; nevertheless, we may perform the operation several times without extracting it: but when it is supposed that there is not sufficient empty space, this acid is to be drawn off by means of a syphon, and, when

we have collected a sufficient quantity of it, it may be substituted for the mixture of vitriolic acid and common salt in the operation we have described, if we have no other use to make of it. That there may pass but a small quantity of muriatic acid, not oxygenated, the first tube ought to form a right angle, or even an obtuse one, with the body matras.

"During the operation, the agitator must be from time to time put in motion, to favour the absorption of the gas by the water; when it is finished, the liquor is of a proper strength to use in bleaching; or we may put a less quantity of water in the tub, and then dilute the liquor according to the proportion already mentioned.

"In this state of concentration, although the liquor has a pretty strong odour, it nevertheless is not hurtful, nor even very unpleasent, to those who use it: it is, however, proper to conduct it into the troughs where the cloths are placed by means of wooden cauals, which are to be connected with the fauset or tube which is at the lower part of the tub."—The following is a description of the apparatus:

ABCD is a reverberatory furnace, having, on a line ^{Plate VII.} with B, many small openings in its circumference, to ^{fig. 1.} serve as chimneys; within which, upon a sand-bath *a*, is placed a matras *b*, the neck of which stands out above the furnace, running through the opening D; which is to be closed with clay. The mouth F, of the neck of the matras, is closed by a cork G, through the middle of which passes a tube H, which forms a communication between the inside of the matras *b*, and the intermediate vessel K, where it also passes through a cork I, which closes one of the three openings of that vessel. The corks G and I ought to be prepared before-hand, and well fitted to each end of the tube of communication H, which is to be so disposed that it may be fitted in immediately after the mixture is made in the matras.

The intermediate vessel K is about an eighth part full of water; into it is plunged the tube of safety L, to prevent danger from regurgitation. This tube ought to be so high, that the weight of the water which enters into it, by the pressure of the gas, may be great enough to cause the gas to pass into the pneumatic tub NOP, by the tube of communication M, which is plunged therein, and reaches to the bottom, where it is bent horizontally, so that the gas may be emitted under the first of the three wooden, or (if they can be procured) stoneware, cavities, or receivers, which are placed in the inside of the tub, one above the other. O is a handle which serves to turn the agitator E, the movement of which facilitates the combination of the gas with the water. P is a spigot and fauset to draw off the liquor.

It is necessary to prepare the cloth by leaving it to ⁴soak for 24 hours in water, or, which is better, in some old ley. Afterwards it should be submitted to the action of one or two good leys; because all the colouring part which may be extracted by the leys would else, without any advantage, consume a part of that liquor, which it is important to be as sparing of as possible. After this, the cloth is to be carefully washed; then it is to be placed in the troughs, without any part being pressed or confined, in such a manner that it may be thoroughly impregnated with the liquor which is to ^{Method of} ^{bleaching.}

leaching. run thereon. The troughs, as well as the tub, ought to be constructed without iron; for that metal, being rusted by the oxygenated muriatic acid, would produce iron moulds, which could not be taken out but by means of salt of sorrel.

The first immersion ought to be longer than the others; it may be continued for three hours, after which the cloth is to be taken out; it is to be again submitted to the action of ley, and then placed in a trough, that fresh liquor may be poured thereon: it is sufficient that this immersion, and the following ones, continue half an hour. When the cloth is taken from the trough, the liquor is to be wrung out, it is to be again submitted to the ley, and afterwards to fresh immersions. The same liquor may serve until its strength is exhausted: when it is much weakened, there may be some fresh liquor added to it. When the cloth appears white, except some black threads and the lifts, it is to be impregnated with black soap, and then strongly rubbed; after which it is to be submitted to the last ley and the last immersion. We cannot determine what number of leys and immersions may be necessary, because it varies according to the nature of the cloth: nevertheless, the limits of this number are between four and eight for linen or hempen cloths.

The manufacturers at Javelle, to whom M. Berthollet had communicated this process, soon after published, in different journals, that they had discovered a particular liquor which had the property of bleaching cloth by an immersion of some hours only. The change they had made in the process, performed in their presence, consisted in putting some alkali into the water which receives the gas; this enables the liquor to become much more concentrated, so that it may be diluted with several times its own quantity of water before it is used.

“These are the proportions which yielded me (says Berthollet), a liquor similar to the pretended Javelle ley: two ounces and a half of common salt, two ounces of sulphuric acid, six drachms of calx of manganese, and, in the vessel where the gas is to be concentrated, one pound of water, and five ounces of potash, which should be dissolved in the water. The Javelle liquor has a somewhat reddish appearance, occasioned by a small quantity of manganese, which either passes in the distillation, because an intermediate vessel is not used, or exists in the potash; most kinds of which contain it, as I have well convinced myself.

“This liquor may be diluted with from ten to twelve parts of water; and, after this, it bleaches more speedily than the liquor itself; but without speaking of the imperfections of the method which is described in the publications from Javelle, and which can only suffice for cotton, we are not able to bleach near the same quantity of cloth with the oxygenated muriatic acid combined in this manner with an alkali, as might be bleached with the same quantity of that acid mixed with water alone; because there is formed a portion of that neutral salt which is known at present by the name of oxygenated muriat of potash, and in which the oxygen becomes concentrated. Now all the oxygen which enters into the composition of this salt is rendered useless for bleaching; because the oxygenated muriat of potash does not destroy colours.”

This method of bleaching was very soon adopted in

Britain, and is now almost universal among bleachers. A great many changes have been made in the process; one of the most important of which is substituting lead vessels for wooden ones, which, besides weakening its action exceedingly, were very soon destroyed by the acid. We believe, too, that the bleachers very generally add some alkali to the acid, notwithstanding the strong objections which Mr Berthollet has made to that manner of bleaching.

This method of bleaching has been found to answer remarkably well: the only objection that has been made to it is, that the cloth is apt to be weakened. And this, no doubt, must be the case, if care be not taken to prevent the acid from being too much concentrated: but we have little doubt that, with a sufficient degree of caution, it will prove as safe as any other whatever; and, in point of expedition, there cannot surely be any comparison drawn between the old mode of bleaching and the new.

It remains for us now to consider whether the new Theory of discoveries in chemistry do not throw some rays of light ⁵ upon the theory of bleaching; for it is only by perfecting the theory that we can advance with certainty in our practical improvements.

It has been already observed, in the article BLEACHING (*Encycl.*), that cloth, after being bleached, was a good deal lighter than it had been before that operation: It follows, therefore, that it must have been deprived of something during the bleaching. Cloth bleached by means of the oxy-muriatic acid likewise undergoes a loss of weight; so that, in all probability, both modes act in precisely the same manner.

If raw linen or thread be boiled in a solution of caustic alkali, properly diluted, it gives out something which tinges the ley of a deep brown, and at the same time the alkali loses its causticity. If the linen be boiled in another similar solution, it communicates the same colour, and even a third may be slightly tinged; but after this, alkalies, unless so much concentrated as to injure the texture of the cloth, have no effect on it whatever. If the linen be now plunged into oxy-muriatic acid, properly prepared, and allowed to remain till it begins to become white, and then plunged into an alkaline ley, the alkali loses its causticity, and assumes the same deep colour that the first ley did. Here, then, we have two alkaline solutions; the one saturated with colouring matter before the action of the oxy-muriatic acid on the linen, the other after it. When these solutions are saturated with an acid, a yellow-coloured precipitate is obtained, which when dried assumes the appearance of a black powder. Precisely the same substance is obtained from both solutions. This colouring matter is almost insoluble in water. Pure or caustic potash dissolves about double its own weight of it; carbonate of potash not so much.

Hence we see the use of alkalies in bleaching. The colouring matter is not soluble in water, but part of it is soluble in alkali. However, after the alkali has exhausted all its power, the linen is not white: colouring matter therefore exists in it, which alkalies cannot act upon. But after being plunged in oxy-muriatic acid, it also becomes soluble in acids. Here, then, is the use of that acid in bleaching—it communicates something to the colouring matter which renders it soluble in alkali. This something, we have already seen, is oxygen. It follows,

Bleaching. follows, therefore, that before the greater part of the colouring matter of linen can be extracted by alkalies, it must be combined with oxygen. It is in producing this combination that the use of the exposure to the sun and air consists; and it is because the oxy-muriatic acid produces it almost instantaneously, that the new mode of bleaching is so much more expeditious than the old.

If into the alkaline solution of the colouring matter lime-water be poured, there takes place a copious precipitate, which consists of the lime and colouring matter combined. Lime, therefore, has a stronger affinity for the colouring matter than alkali has; and as the compound of lime and the colouring matter is not very soluble in water, lime-water might be used to deprive the alkaline ley of the colouring matter which it has imbibed; after which it might be used again. Care, however, must be taken, that no lime-water remains in the ley; otherwise it might precipitate and fix the colouring matter on the linen, after which it would be very difficult to remove it.

6
Nature of the colouring matter of linen.

Irish Transf. 1789.

From an alkaline ley, saturated with the colouring matter of linen yarn, Mr Kirwan, by means of muriatic acid, precipitated the colouring matter. He found it to possess the following properties: When suffered to dry for some time on a filter, it assumed a dark green colour, and felt somewhat clammy like moist clay. "I took (says he) a small portion of it, and added it to 60 times its weight of boiling water, but not a particle of it was dissolved. The remainder I dried in a sand heat; it then assumed a shining black colour, became more brittle, but internally remained of a greenish yellow, and weighed one ounce and a half.

"By treating eight quarts more of the saturated ley in the same manner, I obtained a further quantity of the greenish deposit; on which I made the following experiments:

"1st, Having digested a portion of it in rectified spirit of wine, it communicated to it a reddish hue, and was in a great measure dissolved: but by the affusion of distilled water the solution became milky, and a white deposit was gradually formed; the black matter dissolved in the same manner.

"2dly, Neither the green nor the black matter was soluble in oil of turpentine or linseed oil by a long-continued digestion.

"3dly, The black matter being placed on a red hot iron, burned with a yellow flame and a black smoke, leaving a coaly residuum.

"4thly, The green matter being put into the vitriolic, marine, and nitrous acids, communicated a brownish tinge to the two former, and a greenish to the latter, but did not seem in the least diminished.

"Hence it appears, that the matter extracted by alkalies from linen yarn is a peculiar sort of resin, different from pure resins only by its insolubility in essential oils, and in this respect resembling lacs. I now proceed to examine the power of the different alkalies on this substance. Eight grains of it being digested in a solution of crystallized mineral alkali, saturated in the temperature of 60°, instantly communicated to the solution a dark brown colour; two measures (each of which would contain 11 pennyweights of water) did not entirely dissolve this substance. Two measures of the mild vegetable alkali dissolved the whole.

Bleaching. "One measure of caustic mineral alkali, whose specific gravity was 1,053, dissolved nearly the whole, leaving only a white residuum.

"One measure of caustic vegetable alkali, whose specific gravity was 1,039, dissolved the whole.

"One measure of liver of sulphur, whose specific gravity was 1,170, dissolved the whole.

"One measure of caustic volatile alkali dissolved also a portion of this matter."

The colouring matter of cotton is much more soluble in alkali than that of linen; hence the greater facility with which cotton is bleached.

From these observations, the great importance of alkalies in bleaching, and the necessity of regulating the strength, and ascertaining the purity, of the leys made use of, must be apparent. Manufacturers, therefore, lie under very great obligations to Mr Kirwan, who has lately examined the alkaline matters used in bleaching with his usual accuracy and abilities. The result of his experiments was as follows:

Table of the quantity of mere alkali in 100 Avoirdupois Irish Transf. pounds of the following substances. 1789.

One hundred lbs.	Mineral Alkali.
Crystallized soda	20 lbs.
Sweet barilla	24
Mealy's cunnamara kelp	3,437
Ditto defulphurated by fixed air	4,457
Strangford kelp	1,25
One hundred lbs.	Vegetable Alkali.
Dantzic pearl ash	63,33 lbs.
Clarke's refined ash	26,875
Cashup	19,376
Common raw Irish weed-ash	1,666
Ditto slightly calcined	4,666

When linen is allowed to remain for some time in oxy-muriatic acid, it becomes white. It is evident, then, that when the colouring matter of linen is saturated with oxygen, it becomes colourless: But linen bleached in this manner very soon becomes yellow, especially when exposed to heat. Berthollet, to whose ingenious experiments and observations we are indebted for the greater part of the above remarks, has given the following explanation of the cause of this change: He distilled the colouring matter of linen, and obtained a thick oil, a little ammonia, and $\frac{2}{5}$ of carbon remained behind. The oil contained carbon; and he supposed that carbonic acid gas, and carbonated hydrogen gas, were disengaged. He concluded in consequence, that one-third of this colouring matter was carbon. The other ingredient in the oil was hydrogen; for Lavoisier has proved that oil is composed of oxygen and hydrogen. The colouring matter of linen, then, is composed principally of carbon and hydrogen.

Oxygen combines with hydrogen at a lower temperature than it does with carbon; for if a considerable quantity of oxy-muriatic acid be mixed with a solution of sugar (a substance which consists chiefly of carbon and hydrogen), and the liquor be evaporated, there remains behind little else than carbon, the hydrogen having combined with oxygen and formed water, which had passed off in the form of vapour. Now, whenever a quantity of hydrogen is separated from a body principally

Bleaching. cipally composed of hydrogen and carbon, that body assumes a brown or yellow colour, because the carbon becomes predominant; and this colour becomes the deeper the greater the proportion of the carbon is, compared to that of the hydrogen; and at last, when nothing but carbon remains, it becomes quite black.

It is probable, then, that when the oxy-muriatic acid renders linen white, a quantity of oxygen has combined with the colouring particles; but that this oxygen gradually enters into a combination with the hydrogen, and forms water which passes off; that then the carbon becomes predominant, and the linen in consequence assumes a yellow colour*.

The same method does not succeed in bleaching wool and silk which answers for linen and cotton. One would be disposed to think that these substances are bleached rather by losing oxygen than by absorbing it. Wool, for instance, is rendered white very quickly when exposed to the fumes of sulphurous acid, which we know has a strong affinity for oxygen, and soon saturates itself with it. But what passes during the whitening of animal matters has never yet been properly inquired into, though it would not only greatly elucidate *bleaching*, but *dyeing* likewise, and throw much light upon some of the obscurest parts of chemistry. A great improvement, however, has lately been made by M. Baumé in the manner of bleaching silk. Of this improvement we shall proceed to give an account †.

Before the silk is wound off the cocoons in which the silk worms are enclosed, it is necessary to kill the insects, otherwise they would in all probability eat thro' it and destroy it. This is commonly done by exposing the cocoons, properly wrapped up, for two hours to the heat of about 158 degrees of Fahrenheit in an oven; after which they are kept for a certain time in a mass to preserve their heat, and effectually destroy such of the insects as might have escaped the power of the oven. The effect of this process is, that the silk is hardened, and is more difficult to wind off than before. Hence the product of silk is less by one ninth part in quantity, and inferior in quality to what might have been obtained by winding off without this previous baking. M. Baumé, not only from these views, but likewise because the silk which has not been baked proves susceptible of a greater lustre, was induced to destroy the chrysalis by spirit of wine. For this purpose he disposes them in a wooden box in a stratum six inches deep: upon each square foot half a pint of spirit of wine is to be sprinkled with a small watering-pot made for that purpose. The liquid is to be equally distributed, but it is not necessary that all the cocoons should be wetted. They are then to be mixed by hand. In the next place another stratum is to be formed over the first, nearly of the same depth, which is to be sprinkled and treated as before. By this method of proceeding, the box becomes filled, and must then be covered, and left for 24 hours; during which time they become spontaneously heated to about 100 degrees, and the vapour of the spirit of wine exerts itself with wonderful activity. After this treatment they must be spread out to dry, which happens in a short time, and is absolutely necessary previous to winding off.

The spirit of wine to be used in this operation ought to be of the specific gravity .847, at the temperature of 55 degrees. It is of the greatest importance to use that

Bleaching. spirit only which has been kept in vessels of glass, of tinned copper, or of pure tin. Lead vessels are absolutely to be rejected; wooden vessels tinge the spirit, which gives the silk a degree of colour of considerable permanency, and very inimical to the bleaching process.

The silk is wound off upon a reel, while the cocoons are kept immersed in water almost boiling. Upon this part of the process M. Baumé remarks, 1. That the dead cocoons must be separated. These are known by the brown or black spots on their surface. 2. That well-water, which on account of its clearness is almost universally used in the silk manufactories, mostly contains nitre, and is extremely prejudicial to the bleaching process. The presence of nitrous acid gives a yellow colour, which resists bleaching and even scouring; he therefore recommends river-water. 3. In some countries a small quantity of alum is used. Neither this nor any other saline substance is of the least advantage to the colour, beauty, or quality of the silk.

At the four places of contact of the silk upon the reel, all the threads stick together. It is absolutely necessary that this should be remedied. The method consists in soaking the silk in a sufficient quantity of warm water, at about 90 degrees, for about two hours; after which the threads are to be separated by opening the hanks upon a pin, and lightly rubbing the parts which cohere. When the silk is dry, it is to be loosely folded in its original form, and is ready for bleaching.

The silk while wet is soft, and part of its gummy matter is in such a state, that its threads would readily adhere, if wrung while warm for the purpose of clearing it of the water. After such improper treatment there would be no other remedy than to soak it again in warm water.

The apparatus for bleaching the silk consists of a stone-ware vessel, nearly of a conical form, capable of holding about 12 gallons, having a large opening at the one end, and a smaller of about an inch diameter at the other end. Common pottery cannot be used in this operation, because it is soon rendered unserviceable by the action of the muriatic acid, and the stone-ware itself is not very durable. This vessel must be carefully examined, to ascertain that it does not leak in the slightest degree; after which the inside is to be rubbed with a pumice-stone, to clear it of asperities which might break the threads. A cover of the same material is to be fitted on by grinding; and the smaller aperture, which in the use is the lowest, is to be closed with a good cork, in the middle of which is thrust a small glass tube about a quarter of an inch in diameter; this is likewise stopped with a cork, excepting at the time when it is required to draw off the liquid contents of the jar. A small perforated false bottom is placed within the vessel, to prevent this tube from being obstructed.

Six pounds of yellow raw silk are to be disposed in the earthen pot; upon this is to be poured a mixture, previously made, of 48 pounds of spirit of wine of the specific gravity .867, with 12 ounces of very pure marine acid, absolutely exempt from all presence of nitrous acid, and of the specific gravity 1.114. The pot is then to be covered, and the whole left in digestion till the following day, or until the liquor, which at first assumes a fine green colour, shall begin to assume that of a dusky brown.

The acidulated spirit is then to be drawn off, clear

* Ann de Chim. VI. 210.

7 Bleaching of wool and silk.

† See the memoir in the Ann. de Chim. xvii. 156. and abridged in Nicholson's Journal, I. 32. from which last we have taken our account of it.

New mode of whitening silk.

Bleaching. spirit of wine poured upon the silk, and drawn off repeatedly until it passes colourless. The silk is then suffered to drain without stirring it. In this state it is ready for a second infusion.

Forty-eight pounds of spirit of wine, acidulated with 12 ounces of marine acid, are now to be poured on the silk, and the whole suffered to remain for 24 hours or longer, until the silk becomes perfectly white. The time required for this second infusion is commonly longer than for the first: it sometimes amounts to two, three, or even six days, according to circumstances, particularly the temperature and the nature of the silk. Silk which has been in the oven is in general more difficult to bleach.

When the silk has thus obtained its utmost degree of whiteness, the acidulated spirit is to be drawn off into a separate vessel. This fluid is but slightly coloured, and may be used again in the first infusion of other yellow silk, with the addition of six ounces more of marine acid. The receiving vessel is to be removed, and another clean vessel substituted in its place. The silk is then sprinkled with clean spirit, and occasionally pressed down with the hand. As soon as the spirit of wine comes off absolutely colourless, a third infusion is to be made by pouring upon the silk 48 pounds of the pure spirit without acid, which is to remain till the following day: it is then to be drawn off, and reserved for washing other silk after the first infusion.

After the silk has been left to drain, and affords no more spirit, it still retains its own weight of that fluid. This is recovered by sprinkling the silk with a small quantity of very clear river-water at a time. While the water applies itself and subsides along the silk, it drives the spirit of wine before it, so that the first portions which flow from the tube are scarcely diminished in strength. The addition of water is to be continued until nothing but mere water comes off below.

In this situation the silk is found to be well bleached, but still retains a portion of marine acid sufficient to render it harsh to the touch, and after a time brittle. It must be washed off with water. The best method is to put the silk loosely into a coarse woollen bag, which is to be secured loosely in another cloth like a small bed or pillow, then placed in a basket, and left in a running stream for five or six hours; but where the convenience of a stream is wanting, the earthen pot containing the silk is to be covered with a cloth, and water pumped through it for five or six hours, or until that which issues from the lower aperture gives no red colour to the tincture of turnsol. At this period the lower opening is to be closed, and the vessel filled with water, which must be changed once or twice in 24 hours.

Though the mineral acids are the most powerful and destructive of all saline substances, yet they may be applied to silk when diluted with spirit of wine in very considerable doses. In trials made to ascertain the maximum, two ounces of marine acid were added to one pound of spirit of wine, without altering the silk. Two drams of marine acid cause a very perceptible alteration in one pound of silk.

Spirit of wine which has been mixed with nitrous acid cannot be used in bleaching, even though afterwards rectified upon an alkali, because it still retains a portion of nitrous gas. Pure spirit of wine without acid extracts a fine yellow colour from silk, which does

not separate for years, even though exposed to the sun's light. Yellow silk exposed to the sun, loses its colour in a short time. The acidulated spirit which has been used in the infusion of silk, is changed by exposure to the sun, but not in such a manner as to be rendered fit for use a second time. In order to obtain a beautiful white colour, it is essential that the silk should be immersed in a large quantity of the fluid, especially at the first infusion. Without this management it would become necessary to make three infusions in the acidulated spirit. When the first infusion is well managed, the silk will have lost all its yellow colour, and become considerably white, at the same time that the liquor will have begun to change colour a little. As long as it continues of a fine green, it is certain that it has not exhausted its whole action upon the silk. The duration of this first infusion may be longer or shorter, without inconvenience, according to the temperature. When the temperature is at 77° of Fahrenheit, the first infusion is often made in 10 or 12 hours. In small experiments the heat of the atmosphere may be supplied by the water bath; in which case all the infusions are easily made in the course of a day.

When the first infusion is finished, and the liquor drawn off, the silk appears greenish: the subsequent washings in spirit of wine clear it of the liquor it retained. This sprinkling should be made with the watering pot, otherwise the quantity poured will be greater, and the management more wasteful.

Pieces of gauze and entire garments of silk have been successfully bleached in this way.

The finest natural white silks are rendered infinitely whiter by this process. Spirit of wine alone has the property of depriving yellow silk of its colour, which it brings to the state of the naturally white silk. In this state the silk is disposed to acquire a greater degree of brightness by a single infusion in the acidulated spirit. This process has its advantages over the other, to which it is also inferior in certain respects; concerning neither of which the author has entered into any detail.

The colouring matter was found to be a resin perfectly animalized, affording by distillation the same products as other animal matters, and the concrete volatile alkali.

Silk whitened by scouring may be dried freely in the air without affecting its lustre. This is not the case with the silk bleached in the gum: if it be left at liberty to dry in the air, it resembles white flax without any lustre. The beauty of this silk consists in its shining brilliancy; to secure which it must be dried in a state of tension. Mr Baumé has contrived a simple machine for this purpose. It consists of a strong square frame of wood standing upright upon feet: the upper horizontal bar is six feet long, and has six iron pins driven through it at equal distances, so as to project on each side for the purpose of receiving twelve bobbins. The lower horizontal bar is moveable up and down in a mortice, by means of a screw at each end: it is furnished with six holes adapted to receive as many pins to correspond with those above. The skains of silk are to be dressed and arranged upon wooden pins, as they are taken out of the sack from washing. As soon as there are twelve together, they are to be wrung with a staff; after which the skains are to be hung one by one upon as many bobbins put upon the upper pins of the square frame.

Bleaching. frame. Another bobbin with tails is to be inserted in the lower loop of the skain, and fastened to the corresponding pin of the lower bar, by means of a strap and hook, which need not be described to such as are slightly acquainted with mechanical objects. When the machine is thus supplied with skains on both sides, the lower bar of the frame is to be pressed down by the screws until the silk is moderately stretched. When it is dry, the screws are to be equally slackened, the skains taken off and folded with a slight twist, that they may not become entangled.

To complete the description of this process, it only remains to show how to recover the alcohol, and ensure the purity of the acids made use of.

9 Method of recovering the alcohol used. The alcohol which has been used in bleaching silk is acid, and loaded with colouring matter. In this state it cannot be again used. There are two methods of distilling it which have their respective advantages and inconveniences.

By the first the acid is lost; which is saturated with potash, in order that the distillation may be afterwards performed in a copper alembic. A solution of potash is to be poured into the acid spirit, and stirred about to promote the saturation. Carbonic acid is disengaged with strong effervescence from the alkali; and the point of saturation is known by the usual test, that the fluid does not redden the tincture of turnsol. The distillation is then to be made in the copper alembic, and the alcohol reserved in proper vessels.

In the second process for distilling without alkali, the acid spirit is distributed into a great number of glass retorts, placed in the sand bath, on the gallery of a furnace. The first product is scarcely acid; but what follows is more and more so, and must be kept in vessels of glass or stone-ware, which become embarrassing on account of their number. The fluid which remains in the retorts has the colour of beer slightly turbid, and contains the greatest part of the marine acid. It must be poured into one or more retorts, and concentrated by heat gradually applied. The first liquor which comes over is slightly red, turbid, and scarcely acid. This is to be thrown away, and the receivers changed. The succeeding product is the colourless marine acid, of an aromatic smell resembling the buds of poplar. The resin of the silk remains in the retort decomposed by the acid. The marine acid thus obtained is weaker than it originally was; which is in fact of little consequence, as it is pure, and may be safely used, either by increasing the dose proportional to its diminished strength, or by concentrating it if required in the usual way. If this distillation be made in a silver alembic, instead of retorts of glass, and a capital and worm of pure tin be annexed, the alcohol will be obtained so slightly acid as scarcely to redden the tincture of turnsol; but it is sufficiently acid to receive injury if preserved in a copper vessel.

10 And of preparing a pure muriatic acid. As to the acid, Mr Baumé observes that the muriatic acid of commerce is unfit for the purpose. It was formerly prepared with the marine salt of the saltpetre manufacturers; and even when it is made with good salt, the decomposition is effected with common vitriolic acid which contains nitrous acid. Marine acid mixed with a small quantity of nitrous acid does not prevent the silk from being beautifully whitened: it even accelerates the process considerably, and in the most

satisfactory manner. But the alcohol, every time it is used and rectified, becomes charged with the acid and gas of nitre, which assume the characters of the nitrous anodyne liquor. In this state neither distillations nor repeated rectifications from alkali are sufficient to separate the nitrous matter from the alcohol. Then it is that the success of the operator vanishes, with a degree of rapidity equal to the advances which encouraged his hopes at the commencement.

To purify common sulphuric acid, 100 pounds of it are to be mixed in a large basin of copper with the same quantity of river-water, and stirred with a wooden spatula. The mixture instantly becomes heated to the boiling water point, and a great quantity of red vapour is disengaged, which has the smell of aqua-regia, and arises from the nitric and muriatic acids. When this mixture is made, it is proper to immerse the basin to a suitable depth in a large vessel of water, to hasten the cooling. As soon as it is sufficiently cooled, it is to be drawn off into bottles, and left to become clear during several days. It is in the next place to be decanted, and conveyed into retorts by a syphon funnel, and the rectification proceeded upon until it becomes perfectly white. Towards the end of the operation a small quantity of sulphur sublimes in the neck of the retort. Instead of receivers, a small glass cup is placed beneath the aperture of each retort, in order to facilitate the distillation of the nitric and muriatic acids. When the acid in the retorts is sufficiently cooled, it is poured a second time into the copper basin, and mixed with 100 pounds of river-water, as at first, and again concentrated in the retorts till it becomes perfectly clear. The muriatic acid is to be disengaged from common salt by the application of this acid in the usual manner.

11 The oxy-muriatic acid is also used very generally for bleaching paper, or rather the stuff out of which paper is made. It has been alleged, and we believe with some truth, that since this mode of whitening paper was introduced into this country, the strength of paper is much inferior to what it was formerly. If this be really the case, perhaps it is owing to the use of too concentrated an acid.

We shall finish this article with Mr Chaptal's account of this process, who was the first person that introduced it. "Blotting paper (says he), by being put into oxygenated muriatic acid, is bleached without suffering any injury; and rags of coarse bad cloth, such as are used in the paper manufactories to make this kind of paper, may be bleached by this acid, and will then furnish paper of a very superior quality. I bleached by it an hundred weight of paste, intended to be made into blotting paper, and the increase of value in the product was computed at 25 per cent. whereas the expence of the operation, when calculated in the strictest manner, amounted only to 7 per cent.

12 "The property possessed by this acid, of bleaching paper without injuring its texture, renders it very valuable for restoring old books and smoked prints. The latter, when discoloured to such a degree that the subject of them could hardly be distinguished, were re-established and revived, in so astonishing a manner that they appeared to be new; and old books, soiled by that yellow tinge which time always produces, may be so completely renewed, that one might suppose them to be just come out of the press. The simple immersion of a
 Mode of whitening old books,
 print

Bleaching
||
Boar.

print in oxygenated muriatic acid (leaving it therein a longer or a shorter time, according to the strength of the liquor) is all that is required for bleaching it; but when a book is to be bleached, some farther precautions are to be used. As it is necessary that the acid should wet every one of the leaves, the book must be completely spread open, and then, by letting the boards of the binding rest upon the sides of the vessel, the paper only will be immersed in the liquor. If any of the leaves stick together they must be carefully separated, that all of them may be equally impregnated. The liquor takes a yellow tinge, the paper grows white; and after two or three hours the book may be taken out of the liquor, and soaked in clean water, which should be changed from time to time, in order to wash out the acid with which the book is impregnated, and also to deprive it of the disagreeable smell it has contracted.

“ The above method, which is the first I made use of, has generally succeeded pretty well: too often, however, the leaves of my books have had a motley appearance, and sometimes several pages were not at all bleached; I was therefore obliged to have recourse to the following more certain process. I began by unsewing the books, and reducing them into sheets; these sheets I placed in divisions made in a leaden vessel, by means of thin slips of wood, so that the leaves when laid flat were separated from each other by very small intervals. I then put the acid into the vessel, pouring it against the side, that the leaves might not be disturbed; and when the operation was finished, I drew off the acid by means of a cock fixed in the bottom of the vessel. I then filled the vessel with clean water, which washed the leaves, and took off the smell of the oxygenated acid. They may then be dried, smoothed, and new bound. In this manner I have restored many valuable books, which had become worthless from the bad state they were in.

13.
And prints.

“ When I had to bleach prints so torn to pieces that they consisted only of fragments fitted together, and pasted upon paper, I was afraid I might lose some of these fragments in the liquor, because they separate from the paper by the softening of the paste: in that case therefore I took the precaution of enclosing the print in a large cylindrical bottle, which I turned upside-down, fixing its mouth to that of a vessel in which I had put a mixture proper for disengaging oxygenated muriatic gas. This gas fills the inside of the bottle, and, acting upon the print, takes off the stains, ink-spots, &c. while the fragments remain pasted to the paper, and consequently keep their respective places.”

BLOCKS (*Encycl.* Plate XCV. fig. 5.) *a* Represents a single block, and *b, c*, two double ones of different kinds, without straps; *e, f*, two double tackle blocks, iron bound, the lower one, *f*, being fitted with a swivel; *g*, a double iron block with a large hook; *h*, a small block; *i*, a top block; *k*, a voyal block; *l*, a clew garnet block; *m*, the cat block, employed to draw the anchor up to the cat-head. See *Cat-Heads*, *Encycl.*

CAPE OF LARGE SNOURED BOAR, a species of the genus *Sus*, which, according to M. Vaillant, differs from every known species, and has not been accurately described by any writer of natural history. Buffon, indeed, in the Supplement to his History of Quadrupeds,

has given a figure of it; but nothing like the head of the animal is discoverable, says our author, in that figure, all its characteristics having been omitted by the draughtsman. M. Vaillant, during his last travels in Africa, shot a monstrous boar of this species on the banks of Fish river, and in the country of the *Greater NIMQUAS*. He describes it in the following terms: Its snout, instead of being taper and in the form of a proboscis, is, on the contrary, very broad and square at the end. It has small eyes, at a very little distance from each other, level with the surface, and near the top of the forehead. On each cheek a very thick cartilaginous skin projects horizontally, being about three inches long and as many broad. At first sight you would be tempted to take these excrescences for the ears; particularly as the real ears of the animal, sticking as it were to the neck, which is very short, are partly concealed by an enormous mane, the bristles of which, in colour red, brown, and greyish, are 16 inches in length on the shoulders. Directly below these false ears is a bony protuberance on each side, projecting more than an inch, serving the animal to strike with to the right and left. The boar has, besides, four tusks, of the nature of ivory, two in each jaw: the upper ones are seven or eight inches long; very thick at the base, and terminating in an obtuse point, grooved, and rising perpendicularly as they issue from the lips: the lower ones are much smaller, and so close to the upper ones when the mouth is shut, that they appear as one. The head is a truly hideous object. It is scarcely less so than that of the hippopotamus, to which at first view it appears to have a striking resemblance. Systematists, accustomed to view nature only according to rules established by themselves, will be far from acknowledging this animal to be a boar; for not to mention its large snout, it wants incisive teeth in both jaws. Notwithstanding its wide muzzle, it ploughs up the earth to seek for roots, on which it feeds. It is very active, though large and bulky; running with such speed, that the Hottentots give it the name of the *runner*.

BONNET (Charles), was descended from a French family, who being compelled, on account of their religious principles, to emigrate from their native country, established themselves at Geneva in the year 1572. His grandfather was advanced to the magistracy in that city, and adorned by his integrity an eminent station. His father, who preferred the station of a private citizen, paid unremitting attention to the education of his son, who was born on the 13th of March 1720; and Charles, at a very early period, recompensed his father's assiduity, by the amiableness of his disposition, and the rapid progress he made in general literature. When he was about 16 years of age, he applied himself, with great eagerness, to the perusal of *Le Spectacle de la Nature*; and this work made such a deep impression on his mind, that it may be said to have directed the taste and the studies of his future life. What that publication had commenced, was confirmed by the work of *La Pluche*; but having accidentally seen the treatise of *Reaumur* upon insects, he was in a transport of joy. He was very impatient to procure the book; but as the only copy in Geneva belonged to a public library, and as the librarian was reluctant to intrust it in the hands of a youth, it was with the utmost difficulty that he could obtain his end.

By

Boar,
Bonnet.
Plate VII.

Bonnet.

By the possession of this treasure, our assiduous youth was enabled to make several new and curious experiments, which he communicated to Reaumur himself; and the high applause he gained from so great a naturalist added fresh vigour to his assiduity.

In compliance with his father's desires, he applied himself, though with much reluctance, to the study of the law. The works of *Burlamaqui* pleased him the most, on account of the perspicuous and philosophic manner in which the subject was treated: the institutes of *Heineccius* gave him some courage also, as he perceived order and connection; but the Roman law terrified him as the *hydra of Lerna*. Notwithstanding his application to these authors, he still continued attached to natural history, and was very active in making experiments. The experiments which demonstrate that tree-lice propagate without copulation, was communicated by Reaumur to the Academy of Sciences; and this circumstance occasioned an epistolary correspondence between M. Bonnet and that great naturalist. This was doubtless very flattering to a youth of twenty years. The letter of Reaumur was accompanied with a present of that very book which he had borrowed with so much difficulty two years before.

Animated by such distinguished marks of approbation, he diligently employed every moment he could steal from the study of jurisprudence to the completion of his natural history of the tree-lice; to experiments on the respiration of caterpillars and butterflies, which he discovered to be effected by stigmata, or lateral pores; to an examination of the construction of the tænia or tape-worm; in frequent correspondence with Reaumur; and in assisting Trembley in his discoveries and publication concerning millepedes, &c. Having in the year 1743 obtained the degree of doctor of laws, he relinquished a pursuit which he had commenced with so much reluctance. In the same year he was admitted a fellow of the Royal Society, to which he had communicated a treatise on insects.

Bonnet being now liberated from his other pursuits, applied himself, without intermission, to collecting together his experiments and observations concerning the tree-lice and the worm, which he published in 1744 under the title of *Insectology*. This work acquired deserved approbation from the public, and was honoured by the commendation of the celebrated B. de Jussieu. He was reproached, however, in a periodical publication, with having paid too little attention to the delicacy of his reader; though his patience and accuracy were acknowledged to be deserving of praise. Such unremitting application and labour could not fail of becoming injurious to his health. Inflammations, nervous fever, sore eyes, &c. compelled him to relinquish the use of the microscope and the study of insects. This prevention was so extremely mortifying to a man of his taste and activity of mind, that he was thrown into a deep melancholy, which could only be subdued by the resolution inspired by philosophy, and the consolations of religion: these gradually roused him from a dejected state of mind. About the end of the year 1746 our philosopher was chosen member of the Literary Institution at Bologna, which introduced him to a correspondence with the famed Zanotti, who may be deemed the Fontenelle of Italy.

In the year 1747 he undertook a very difficult work

on the leaves of plants; which, of all his publications in natural history, bore the strongest marks of originality, both with respect to the manner in which his experiments were made, and the discoveries resulting from them. His extreme attachment to natural history gradually led him to a study of a very different nature; speculative philosophy now engaged his whole attention. The first fruits of his meditations in this department was his *Essay on Psychology*. In this work the principal facts observable in human nature, and the consequences resulting from them, are stated in a concise and conspicuous manner. He contemplated man from the first moment of his existence, and pursued the development of his senses and faculties from simple growth up to intelligence. The work, which was published without his name, met with great opposition, and was criticised with severity; but the censures were directed more against his expressions than his principles; nor were they of sufficient importance to impede the general acceptance of the publication.

His analysis of the mental faculties was simply a development of the ideas contained in the preceding work. It engaged his incessant attention for the space of five years; nor was it completed before 1759. It is somewhat singular that both he and the Abbé de Condillac should have illustrated their principles by the supposition of a statue, organized like the human body, which they conceived to be gradually inspired with a soul, and the progressive development of whose powers they carefully traced. In the year 1760 this work was published at Copenhagen, by order and at the expence of Frederick V. and it was followed in 1762 by contemplations on organized bodies. In this the author had three principal objects before him: the first was to give a concise view of every thing which appears interesting in natural history, respecting the origin, development, and reproduction of organized bodies; the second was to confute the two different systems founded upon the Epigenesis; and the third was to explain the system of Germs, indicate the ground upon which it was founded, its correspondence with facts, and the consequences resulting from it. This work was received with much satisfaction by natural philosophers. The Academy of Berlin, which had proposed the same subject as a prize question for 1761, declared that they considered the treatise as the offspring of close observation and profound reasoning; and that the author would have had an indubitable right to the prize, if he had confined his labours to the precise statement of the question. It must also be recorded, to the honour of the great *Malesherbes*, that he reversed the interdiction which the public censor had laid upon this book, under the pretext that it contained dangerous principles.

The Contemplation of Nature appeared in 1764. In this work the author first enlarged upon the common conceptions entertained concerning the existence and perfections of God; and of the order and uniformity observable in the universe. He next descends to man, examines the parts of his composition, and the various capacities with which he is endowed. He next proceeds to the plants; assembles and describes the laws of their economy; and, finally, he examines the insects, indicates the principal circumstances in which they differ from larger animals, and points out the philosophical inferences that may legitimately be deduced from these

Bonnet.

Bonnet, these differences; and he concludes with observations respecting the industry of insects. This work being of a popular nature, the author spared no pains in bestowing upon it those ornaments of which it was susceptible. The principles which he thus discovered and explained, induced him to plan a *system of moral philosophy*; which, according to his ideas, consisted solely in the observance of that relation in which man is placed, respecting all the beings that surround him. The first branch would have comprehended, various means which philosophy and the medical science have discovered for the prevention of disease, the preservation and augmentation of the corporeal powers, and the better exertion of their force: in the second, he proposed to shew, that natural philosophy has a powerful tendency to embellish and improve our mind, and augment the number of our rational amusements, while it is replete with beneficial effects respecting the society at large. To manifest the invalidity of opinions, merely hypothetical, he undertook, in the third place, to examine, whether there were not truths within the compass of human knowledge, to which the most sceptical philosopher must be compelled to yield his consent, and which might serve as the basis of all our reasonings concerning man and his various relations. He then would have directed his attention to a first cause, and have manifested how greatly the idea of a Deity and Supreme Lawgiver favoured the conclusions which reason had drawn from the nature and properties of things: but it is deeply to be regretted that his health, impaired by incessant labour, would not permit him to complete the design.

His last publication was the *Palingenesis*, which treats of the prior existence and future state of living beings.

Of his publications in natural history, those deemed the most excellent are, his Treatise on the best Means of Preserving Insects and Fish in Cabinets of Natural History; a Dissertation on the Loves of the Plants; sundry pieces on the Experiments of *Spallanzani*, concerning the Reproduction of the Head of the Snail; a Dissertation on the *Pipa*, or Surinam Tod; and different Treatises on Bees.

In the year 1783 he was elected honorary member of the Academy of Sciences at Paris; and of the Academy of Sciences and the Belles Lettres at Berlin.

Much of his time was employed in a very extensive correspondence with some of the most celebrated natural philosophers and others. Of this number were *Reaumur*, *De Geer* the Reaumur of Sweden, *Du Hamel*, the learned *Haller*, the experimental philosopher *Spallanzani*, *Van Swieten*, *Merian*, and that ornament of Switzerland the great *Lambert*. He entertained, however, the utmost aversion to controversy. He thought that no advantage to be obtained by it could compensate for the loss of that repose which he valued, with Newton, as the *rem prorsus substantialem*. He never answered remarks that were made to the prejudice of his writings, but left the decision with the public; yet, ever ready to acknowledge his errors, he was sincerely thankful to every one who contributed to the perfection of his works. He was used to say that one confession, *I was in the wrong*, is of more value than a thousand ingenious confutations.

His literary occupations, and the care he was obliged to take of his health, prevented him from travelling.

He delighted in retirement, and every hour was occupied in the improvement of his mind. The last 25 years of his life were spent in the same rural situation where he had passed the greater part of his early days; yet notwithstanding the pursuit of literature was his supreme delight, he never refused to suspend his studies, when the good of his country seemed to demand his services.

He was chosen in 1752 member of the Grand Council in the republic of Geneva: and he assisted regularly at their deliberations till the year 1768, where he distinguished himself by his eloquence; his moderation, united with firmness; by his good sense and penetration in cases of difficulty; and by the zeal with which he endeavoured to reclaim his fellow-citizens to that ancient simplicity of manners which had been so conducive to the welfare of the state, and to the love of virtue, so essential to the existence of genuine liberty. His conduct, in every case, was consistent with his principles. He took no pains to accumulate wealth, but remained satisfied with a fortune equal to his moderate wants, and to the exercise of his benevolence. The perfect correspondence between his extensive knowledge and virtuous deeds procured him universal esteem.

In the year 1788 evident symptoms of an *hydrops pectoris* manifested themselves; and from this time he gradually declined. He sustained his indisposition with unremitting cheerfulness and composure. After various fluctuations, usual in that complaint, he died on the 20th of May 1793, in the 73d year of his age; retaining his presence of mind to the last moment, administering comfort to surrounding friends and relatives, and attempting to alleviate the distress of his disconsolate wife, in whose arms he expired.

As a demonstration of the high value placed upon his labours and talents by the literati, we have only to remark, that he was member of most of the learned societies of Europe.

BOOK-KEEPING, is an art of which the importance is universally known; and as commonly practised, it has been sufficiently explained in the *Encyclopædia Britannica*. But since that article was written, a great improvement has been introduced into the art, or rather a new method of book-keeping has been invented by Mr EDWARD THOMAS JONES of the city of Bristol, accountant, who calls it the *English system of book-keeping*; and thinks that by it accounts may be more regularly kept, and errors in accounts more easily detected, than by any other method hitherto known. We are much inclined to be of his opinion; and shall therefore lay before our readers his description of this method, as we find it in the specification of the patent which was granted to him January 26. 1796.

The *English System of Book-Keeping* requires three books, called a *day-book* or *journal*, an *alphabet*, and a *ledger*, which must be ruled after the following method, *viz.* the day-book to have three columns on each page, for receiving the amount of the transactions; one column of which to receive the amount of debits and credits, one column to receive the debits only, and one column to receive the credits only; or it may be ruled with only two columns on each page, one column to receive the amount of the debits, and one column to receive the amount of the credits. There must also be on each page of the day-book four other columns ruled,

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two on the left side next the amount of the debits, and two on the right side next the amount of the credits, for receiving the letter or mark of posting, and the page of the ledger to which each amount is to be posted.

The alphabet need not be ruled at all; but must contain the name of every account in the ledger, the letter that is annexed to it as a mark of posting, and the page of the ledger.

The ledger must be ruled with three, four, five, or seven columns on each page, as may be most agreeable, for receiving the amounts of the different transactions entered in the day-book. And the process for using these books, or making up books of accounts on this plan, is as follows:

When a person enters into trade, whether by himself or with copartners, he must have an account opened with himself in the ledger; entering first in the day-book, and then to the credit of his account in the ledger, the amount of the property he advances into trade: The account may be headed either with his name only, or else called his stock-account.

If you buy goods, give the person credit of whom you purchase; when you sell goods, debit the person to whom said goods are sold. If you pay money, debit the person to whom paid, not only for what you pay, but also for any discount or abatement he may allow, and give the cashier credit for the neat amount paid. If you receive money, credit the person of whom you receive it, not only for what he pays, but also for any discount or abatement you may allow, and debit the cashier for the neat amount received; taking care in these entries to have nothing mysterious or obscure, but merely a plain narrative of the fact, introducing not one useless word, and avoiding every technical term or phrase except the words debit and credit, which are full and comprehensive, and the only terms that are applicable to every transaction, and may be affixed to every entry.

But as a hurry of business will sometimes take place in almost every counting-house, which may cause the entries to be made to the debit instead of the credit of an account in the day-book, and to the credit instead of the debit, Mr Jones has endeavoured as much as possible to counteract the evil, by having only one column for receiving the amount of every transaction, whether debits or credits, at the instant of making the entry; and, for the convenience of separating the debits from the credits, previous to posting, which is necessary to prevent confusion and perplexity, he has two other columns on the same page; that on the left side into which the amount of every debit must be carefully entered, and that on the right for the amount of the credits, which columns must be cast up once a month. The column of debits and credits of itself forming one amount; the column for the debits producing a second amount; and the column of credits a third amount; which second and third amounts added together, must exactly agree with the first amount, or the work is not done right.

By this means the man of business may obtain monthly such a statement of his affairs as will show how much he owes for that month, and how much is owing to him; and the debits being added together for any given time, with the value of the stock of goods on hand, will, when the amount of the credit is subtracted therefrom, shew the profits of the trade.

Our author now proceeds to the process of posting:

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which begins with opening an account in the ledger with every person to whose debit or credit there has been an entry made in the day-book; affixing to each account a letter, which is to be used as a mark of posting. The person's name, place of abode, and the folio of the ledger, must then be entered in the alphabet, with the same letter prefixed to each name as is affixed to the account in the ledger. Next, the page of the ledger on which each account is opened (and which will be seen in the alphabet) must be affixed to each amount in the day-book, in the column for that purpose. The date and amount of each debit must then be posted in the columns for receiving it in the ledger, on the left or debit side of that account to which it relates; entering, as a mark of posting in the day-book, against each amount, the same letter that is affixed to the account in the ledger, to which said amount may be posted. Observing that the debits of January, February, March, &c. must be posted into the column for those months in the ledger, and the credits must also be posted in like manner, filling up each account in the centre, at the expiration of every month, with the whole amount of the month's transactions; thus having, in a small space, the whole statement of each person's account for the year; in the columns to the right and left the amount separately of each transaction; and in the centre a monthly statement.

Having described the process of this method of book-keeping, he thus shews how to examine books kept by this method, so as to ascertain, to an absolute certainty, if the ledger be a true representation of the day-book; *i. e.* not only if each transaction be correctly posted, as to the amount thereof, but also if it be rightly entered to the debit or credit of its proper account. This examination differs from the modes that have heretofore been practised, as well in expedition as in the certain accuracy which attends the process; it being only necessary to cast up the columns through the ledger debits and credits, according to the examples given; and the amount of those columns, if right, must agree with the columns in the day-book for the same corresponding space of time. These castings should take place once a month; and if the amounts do not agree, the posting must then, but not else, be called over: and when the time, whether it be one, two, three, or four months, that is allotted to each column of the ledger is expired, the amount of each column should be put at the bottom of the first page, and carried forward to the bottom of the next, and so on to the end of the accounts; taking care that the amount in the day-book, of each month's transactions, be brought into one gross amount for the same time.

Although this process must prove that the ledger contains the whole contents of the day-book, and neither more nor less, yet it is not complete without the mode of ascertaining if each entry be posted to its right account; which may be ascertained by the following method: He has laid down a rule that a letter, which may be used alphabetically in any form or shape that is agreeable, shall be affixed to each account in the ledger, and the same letter prefixed to the names in the alphabet, these letters being used as marks of posting, and affixed to each account in the day-book as it is posted: it is only necessary therefore to compare and see that the letter affixed to each entry in the day-book is the same

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same as is prefixed to the same name in the alphabet; a difference here shews of course an error, or else it must be right.

At the end of the year, or at any other time, when persons balance their accounts, if there be no objections to the profits of the trade appearing in the books, the stock of goods on hand at prime cost may be entered in the day-book, either the value in one amount, or the particulars specified, as may be most expedient, and an account opened for it in the ledger, to the debit of which it must be posted. The casting up of the ledger must then be completed: and when found to agree with the day-book, and the amount placed at the bottom of each column, subtract the credits from the debits, and it will shew the profit of the trade; unless the credits be the greater amount, which will shew a loss. In taking off the balances of the ledger, one rule must be observed, and it cannot be done wrong: As you proceed, first see the difference between the whole amounts of the credits and debits on each page for the year, with which the difference of the outstanding balances of the several accounts on each page must exactly agree, or the balances will not be taken right. By this means every page will be proved as you proceed, and the balances of ten thousand ledgers, on this plan, could not unobservedly be taken off wrong.

BOSCOVICH (Roger Joseph), one of the most eminent mathematicians and philosophers of the present age, was born of virtuous and pious parents, on the 11th of May 1711, in the city of Ragusa, the capital of a small republic of the same name, lying on the eastern coast of the Adriatic Sea. At baptism, the name of Roger was given him, to which he added that of Joseph when he received the sacrament (A) of confirmation.

He studied Latin grammar in the schools which were taught by the Jesuits in his native city. Here it soon appeared that he was endued with superior talents for the acquisition of learning. He received knowledge with great facility, and retained it with equal firmness. None of his companions more readily perceived the meaning of any precept than he; none more justly applied general rules to the particular cases contained under them. He enounced his thoughts with great perspicuity, and came soon to compose with propriety and elegance. His application was equal to his capacity, and his progress was rapid. At the beginning of the 15th year of his age, he had already gone through the grammar classes with applause, and had studied rhetoric for some months. His moral behaviour had likewise been very good: he was respectful and obedient to his parents and masters, affable and obliging to his equals, and exemplary in all the duties of religion. It was now time for him to determine what course he would steer through life; nor did he hesitate long in coming to a resolution.

The Jesuit fathers, by teaching the sciences to youth, were very useful, and at the same time had a fine opportunity of observing their scholars, and of drawing into their society those boys who seemed fit for their

purpose. Such a subject as the young Boscovich could not escape their attention. They shewed him particular kindness, to which he was not insensible. He had an ardent thirst for learning; to advance in which he felt himself capable; and he thought he could nowhere have a better opportunity of gratifying this laudable inclination than in their order, in which so many persons had shone in the republic of letters. Accordingly, with the consent of his parents, he petitioned to be received among them; and his petition was immediately granted, because it was desired by those to whom it was made.

It was a maxim with the Jesuits to place their most eminent subjects at Rome, as it was of importance for them to make a good figure on that great theatre. Wherefore, as Roger's masters had formed great expectations of him, they procured his being called to that city; whither he was sent in the year 1725, and entered the noviceship with great alacrity. This noviceship was a space of two years, in which the candidate made a trial of his new state of life; and in the mean time his new superiors observed him, and deliberated whether or not they would admit him into their body. During these two years, the novice was principally employed in exercises of piety, in studying books of Christian morality, and in becoming perfectly acquainted with the rules and constitutions of the order. After these two years were past, the Jesuits were willing to retain Boscovich, and he was no less desirous of remaining with them. He therefore passed to the school of rhetoric; in which, for two other years under the most expert masters of the society, young men perfected themselves in the arts of writing and speaking, which was of so great consequence to persons who were destined to treat to much with their neighbours. Here Boscovich became perfectly well acquainted with all the classical authors, and applied with some predilection to Latin poetry.

After this he removed from the noviciate to the Roman College, in order to study philosophy, which he did for three years. In order to understand the doctrine of physics, it was necessary to premise the knowledge of the elements of geometry, which is also otherwise proper for forming the mind, and for giving to it a true taste for truth. Here it was that our young philosopher came to be in his true element; and it now appeared how extremely fit his genius was for this kind of study. His master, though he was able and expert, instead of leading him on, was scarcely able to keep pace with him, and his disciples were left far behind. He likewise found the application of the mathematics to natural philosophy pleasant and easy. From all this, before the end of the three years, he had made a great advancement in physical and mathematical knowledge; and his great merit was generally acknowledged by his companions, and well known to his superiors. He had already begun to give private lessons on mathematics.

According to the ordinary course followed by the Jesuits, their young men, after studying philosophy,

were

(A) For this article we are indebted to a dignified clergyman of the church of Rome, who was one of Boscovich's favourite pupils.

Boscovich. were wont to be employed in teaching Latin and the belles lettres for the space of five years, that so they might become still better acquainted with polite learning, and arrive at the study of theology and the priesthood at a riper age. But as Roger had discovered extraordinary talents for geometrical studies, it was thought by his superiors that it would be a pity to detain him from his favourite pursuits in a drudgery for which so many others were fit enough. He was therefore dispensed with from teaching those schools, and was commanded to commence the study of divinity.

During the four years that he applied to that sublime science, he still found some leisure for geometry and physics; and even before that space was ended, he was named professor of his beloved mathematics.

He was now placed in an office for which he was superlatively fit, and for which he had a particular predilection. Besides having seen all the best modern productions on mathematical subjects, he studied diligently the ancient geometricians, and from them learned that exact manner of reasoning which is to be observed in all his works. Although he himself perceived easily the concatenation of mathematical truths, and could follow them into their most abstruse recesses, yet he accommodated himself with a fatherly condescension to the weaker capacities of his scholars, and made every demonstration clearly intelligible to them. When he perceived that any of his disciples were capable of advancing faster than the rest, he himself would propose his giving them private lessons, that so they might not lose their time; or he would propose to them proper books, with directions how to study them by themselves, being always ready to solve difficulties that might occur to them.

To the end that he might be the more useful to his scholars, he took time from higher pursuits to compose new elements of arithmetic, algebra, plain and solid geometry, and of plain and spheric trigonometry; and although these subjects had been well treated by a great many authors, yet Boscovich's work will always be esteemed by good judges as a masterly performance, well adapted to the purpose for which it was intended. To this he afterwards added a new exposition of conic sections; in which, from one general definition, he draws, with admirable perspicuity, all the properties of those three most useful curves. He had meditated a complete body of pure and mixed mathematics, in which were to be comprehended treatises on music, and on civil and military architecture; but from accomplishing this he was prevented by other necessary occupations.

According to the custom of schools, every class in the Roman College, towards the end of the scholastic year, gave to the public specimens of their proficiency. With this view Boscovich published yearly a dissertation on some interesting physico-mathematical subject. The doctrine of this dissertation was defended publicly by some of his scholars, assisted by their master. At these literary dissertations there was always a numerous concourse of the most learned men in Rome. His new opinions in philosophy were here rigorously examined and warmly controverted by persons well versed in physical studies: but he proposed nothing without solid grounds; he had foreseen all their objections, answered them victoriously, and always came off with great applause and increase of reputation. He publish-

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ed likewise dissertations on other occasions; and these works, though small in size, are very valuable both for the matter they contain, and also for the manner in which it is treated. The principal subjects of these dissertations are the following: The spots in the sun; the transit of mercury under the sun; the geometrical construction of spheric trigonometry; the aurora borealis; a new use of the telescope for the determination of celestial objects; the figure of the earth; the arguments made use of by the ancients to prove the rotundity of the same; the circles which are called osculators; the motion of bodies projected in a space void of resistance; the nature of infinities and of infinitely little quantities; the inequality of gravity in different parts of the earth; the annual aberration of the fixed stars; the limits of the certainty to which astronomical observations can arrive; a discussion on the whole of astronomy; the motion of a body attracted by certain forces towards an immoveable centre in spaces void of resistance; a mechanical problem on the solid of greatest attraction; a new method of using the observation of the phases in the lunar eclipses; the cycloid; the logarithmic and certain other curve lines; the forces that are called *living*; the comets; the flux and reflux of the sea; light; whirlwinds; a demonstration and illustration of a passage in Newton concerning the rainbow; the demonstration and illustration of a method given by Euler, regarding the calculation of fractions; the determination of the orbits of a planet by means of catoptrics, certain conditions of its motions being given; the centre of gravity and that of magnitude; the atmosphere of the moon; the law of continuity, and the consequences of it in the elements of matter and their forces; the law of the forces that exist in nature; lenses and dioptrical telescopes; the perturbation which appears to be caused mutually by Jupiter and Saturn, and that chiefly about the time of their conjunction; the divisibility of matter and the elements of bodies; the objective micrometer;—besides other subjects of the like nature, of which he has treated in separate pieces, or in communications inserted in the transactions of literary societies or academies, he being a member of those that are most famous in Europe. It was in some of the above-mentioned dissertations that Boscovich made known first to the world his sentiments concerning the nature of body, which he afterwards digested into a regular theory, which is justly become so famous among the learned.

Father Noceti, another Jesuit, had composed two excellent poems on the rainbow and the aurora borealis. These poems were published with learned annotations by Boscovich; in which, among other things, he with great sagacity discovers errors in optics into which De Dominis, Kepler, and others, had fallen.

His countryman, Benedict Stayer, after having published the philosophy of Descartes in Latin verse, attempted the same with regard to the more modern and more true philosophy, and has executed it with wonderful success, to the admiration of all good judges. The two first volumes of this elegant and accurate work were published with annotations and supplements by Boscovich. These supplements are so many short dissertations on the most important parts of physics and mathematics. Here is to be found a solution of the problem of the centre of oscillation, to which Huygens had

Boscovich. had come by a wrong method; here he confutes Euler, who had imagined that the *vis inertia* was necessary in matter; here he refutes the ingenious efforts of Riccati on the Leibnitzian opinion of the forces called *living*. He likewise shews the falsehood of the mathematical prejudice, according to which the right line is considered as essentially more simple than curves, and makes it appear that the notion of the said right line is commonly accompanied with many paradoxes. He demonstrates, by the doctrine of combinations, some beautiful theorems concerning the space occupied by the small masses of body, with many useful observations on space and time.

Benedict XIV. who was a great encourager of learning, and a beneficent patron of learned men, was not ignorant how valuable a subject Rome possessed in Boscovich; and this pope gave him many proofs of the esteem he had for him. Two fissures which had been perceived in the cupola of the church of St Peter's on the Vatican had occasioned some alarm. The pope desired Boscovich and some other mathematicians to make their observations, and give their opinion on the same. They obeyed, and their opinion was printed. They shewed that there was no cause to apprehend danger; but, for greater security, they proposed certain precautions, which were adopted and put in execution.

The high opinion which the pope had formed of his talents, and the favour in which he was with Cardinal Valenti, minister of state, proved hinderances to his going to America, for which a proposal was made to him by the court of Lisbon. Some differences had long subsisted between Spain and Portugal concerning the boundaries of their respective dominions in that great continent; and John V. of Portugal wished that Boscovich would go over and make a topographical survey of the country in dispute. He was not unwilling to undertake such a task, which was entirely to his taste; and he was resolved at the same time to measure a degree of the meridian in Brazil, which might be compared with that measured at Quito by the French academicians Bouguer and Condamine, with the Spaniards Ulloa and Doy. But the pope hearing of this proposal, signified to the Portuguese minister at Rome, that his master must needs excuse him for detaining Boscovich in Italy, where he had occasion for him, and could by no means consent to part with him.

Accordingly a commission was given to Boscovich by Benedict to correct the maps of the papal estate, and to measure a degree of the meridian passing through the same. This he performed with great accuracy, assisted by F. Christopher Maire an English Jesuit, and likewise a great mathematician. Their map was engraved at Rome, and is perhaps the most exact piece of the kind that ever was printed, as all the places are laid down from triangular observations made by the ablest hands. Boscovich also published, in a quarto volume in Latin, an account of the whole expedition, which appeared at Rome in the year 1755, and was afterwards printed at Paris in French in the year 1770. Here he gives a detail of their observations and of the methods they followed, and likewise of the difficulties they encountered, and how they were surmounted. One of these embarrassed them a good deal at the time, but was afterwards matter of diversion to them and others. Some of the inhabitants of the Apennines, seeing them

pas from hill to hill with poles and strange machines, imagined that they were magicians come among their mountains in search of hidden treasures, of which they had some traditions: and as tempests of thunder and hail happened about the same time, they supposed that these calamities were caused by the forceries of their new visitants. They therefore insisted that Boscovich and Maire should depart; and it was not easy to convince them that their operations were harmless. In this work there is inserted a description of the instruments made use of in determining the extent of the degree of the meridian; and the whole work may be extremely useful to practical geometricians and astronomers.

In the year 1757 the republic of Lucca intrusted Boscovich with the management of an affair which was to them of considerable importance. Between that republic and the regency of Tuscany there had arisen a disagreeable dispute concerning the draining of a lake, and the direction to be given to some waters near the boundaries of the two states. The Lucchese senate chose our philosopher to treat of this business on their part. He repaired to the spot, considered it attentively, and drew up a writing, accompanied with a map, to shew more clearly what appeared to him most equitable and most advantageous for both parties. In order to enforce his reasons the more effectually, it was thought proper that he should go to Vienna, where the Emperor Francis I. who was likewise grand duke of Tuscany, resided. He was so successful in this negotiation, that he obtained every thing that Lucca desired, and at the same time acquired great esteem at the Imperial court. In proof of this, the Empress Queen made his opinion be asked concerning the stability of the Cesarean library, and the repairs to be made in it; which he gave in writing, and it was received with thanks, as being very well grounded.

When he had concluded the affair which had brought him to Vienna, he foresaw that, for a month or two, the snows in the Alps would not allow him to return to Italy. He therefore resolved to employ that time in completing his system of natural philosophy, on which he had been meditating for the space of thirteen years. He published his work on that great subject in the beginning of the year 1758, in the above-mentioned city. We shall in the end give an account of that celebrated system, and here go on with our narration.

On his return to Lucca, he not only met with the approbation of all he had done for the interest of the republic; but also the senate, in testimony of their gratitude, made him presents, and enrolled him in the number of their nobility, which was the greatest honour they had in their power to confer on him.

He, who was thus useful to foreigners, could not refuse to be serviceable to his own country when an occasion of being so offered itself. The British ministry had been informed, that ships of war, for the French, had been built and fitted out in the sea-ports of Ragusa, and had signified their displeasure on that account. This occasioned uneasiness to the senate of Ragusa, as their subjects are very sea-faring, and much employed in the carrying-trade; and therefore it would have been inconvenient for them to have caused any disgust against them in the principal maritime power. Their countryman Boscovich was desired to go to London, in order to satisfy that court on the above-mentioned head; and

Boscovich. and with this desire he complied cheerfully on many accounts. His success at London was equal to that at Vienna. He pleaded the cause of his countrymen effectually there, and that without giving any offence to the French, with whom Ragusa soon after entered into a treaty of commerce.

Boscovich came to London the more willingly, as he was desirous of conversing with the learned men of Britain. He was received by the president and principal members of the Royal Society with great respect; and to that great body he dedicated his poem on the eclipses of the sun and moon, which was printed on this occasion at London, in the year 1760. This is one of his works on which he himself put the greatest value, and it has been much esteemed by the learned. An edition of it was published at Venice the year following, and a third at Paris, which is the most correct: a translation of it into French has likewise been published at Paris. In this very elegant Latin poem he gives an exact compend of astronomy, which serves as an introduction to the subject; he then explains all that belongs to the doctrine of eclipses, and their use in geography; he considers the phenomena that are observed in the eclipses of the sun, and likewise of the moon; he proposes a theorem, which is his own, concerning the distribution of light refracted from the atmosphere of the earth by the shadow of the moon, which happens in the lunar eclipses; he explains the phenomenon of the reddish colour which often appears in the moon when she is eclipsed, of which a sufficient explication had not before been given: this the author draws from the fundamental doctrine of Newton's theory concerning light and colours; and hence takes occasion to give a clear idea of the principal consequences of the said theory. All this is clothed with a beautiful poetical dress, and is adorned with pleasant episodes, not to mention the learned annotations which are subjoined. This poem was composed, for the most part, whilst the author was in journeys, or by way of amusement, when he was obliged to wait for the opportunities of making astronomical observations.

The fellows of the Royal Society invited Boscovich to accompany some of their number to America, to observe the transit of Venus, which was to happen in the year 1762; but being otherwise engaged, he could not accept of that invitation. He intended, however, by all means to observe that remarkable phenomenon, and had fixed on Constantinople as a proper place for doing so. He was conducted thither in a Venetian man of war, and much honoured by one of the baylos of that republic, who commanded the vessel; but, to his great regret, they arrived too late. He returned, by land, in the company of the English ambassador; and a relation of that journey was published in French and afterwards in Italian.

During these journeys, Boscovich's place in the Roman College was well filled by some of those whom he himself had trained up in mathematical learning. He was now called by the senate of Milan to teach mathematics in the university of Pavia, with the offer of a very considerable salary. He and his superiors thought proper to accede to this proposal, and he was received without being subjected to any previous examination; which was always observed, excepting in such an extraordinary case, by the decrees of the university. Here

he taught, with great applause, for the space of six years, having at the same time the care of the observatory of the Royal College of Brera. About the year 1770, the Empress Queen made him professor of astronomy and optics in the Palatine schools of Milan; requiring of him, however, that he should continue to improve the observatory of Brera; which, under his direction, became one of the most perfect in Europe.

Here he was extremely happy, teaching the sciences, applying to his favourite studies, and conversing and corresponding with men of learning and of polished manners; when an event happened which caused to him the most sensible affliction. In the year 1773, the society to which he belonged, and to which he had been from his youth warmly attached, was, to his great regret and disappointment, abolished. They who had been Jesuits were allowed no longer to teach publicly; nor was there any exception made in favour of Boscovich, neither (such was his humour then) would he have accepted of it, though it had been offered him. Proposals were made to him by several persons of distinction: and, after some deliberation, he chose Paris for his place of abode; to which he was induced by the circumstance of his being intimately acquainted with the prime minister at that court. He had not been many months at Paris when the university of Pisa sent him an invitation to go thither, in order to profess astronomy. But the French minister, understanding this, declared to the minister of Tuscany, that it was the intention of his most Christian majesty to make his dominions agreeable to Boscovich, by giving him liberal appointments. In fact he was soon naturalized, and two large pensions were bestowed on him: the one as an honourable support, to the end that he might prosecute his sublime studies at his ease and in affluence; the other as a salary annexed to a new office, created in his favour, under the name of *Director of Optics for the Sea Service*, and with the sole obligation of perfecting the lenses which are used in achromatical telescopes.

At Paris he remained ten years, applying principally to optics, and much regarded, not only by the most reasonable men of letters, but likewise by the princes and ministers, both of France and of other nations. But the greatest men are not exempt from being envied. Some of the French were displeased that a foreigner should appear superior to themselves; others of them could not forget that Boscovich had discovered and exposed their mistakes. The irreligion which prevailed too much among those who bore the name of philosophers, was disagreeable to him. These, and other such circumstances, made him wearied of Paris, and he desired to revisit his friends in Italy; for which purpose he obtained leave of absence for two years.

The first place in Italy in which he made any stay was at Bassano, a town in the territories of Venice. Here, mindful of his obligations, he printed what he had been preparing for the press during his stay in France; and this composes five volumes in large octavo, and is a treasure of optical and astronomical knowledge. The subjects treated of in these volumes are as follow: A new instrument for determining the refracting and diverging forces of diaphanous bodies; a demonstration of the falsehood of the Newtonian analogy between light and sound; the algebraic formulæ regarding the focuses of lenses, and their applications for calculating the spheri-

Boscovich. city of those which are to be used in achromatical telescopes; the corrections to be made in ocular lenses, and the errors of the sphericity of certain glasses; the causes which hinder the exact union of the solar rays by means of the great burning glasses, and the determination of the loss arising from it; the method of determining the different velocities of light passing through different mediums by means of two dioptrical telescopes, one common, the other of a new kind, containing water between the objective glass and the place of the image; a new kind of objective micrometers; the defects and inutility of a dioptrical telescope proposed and made at Paris, which gives two images of the same object, the one direct, the other inverse, with two contrary motions of moveable objects; masses floating in the atmosphere, as hail of an extraordinary size, seen on the sun with the telescope, and resembling spots; the astronomical refractions, and various methods for determining them; various methods for determining the orbits of comets and of the new planet, with copious applications of these doctrines to other astronomical subjects, and still more generally to geometry and to the science of calculation; the errors, the rectifications, and the use of quadrants, of sextants, of astronomical sectors, of the meridian line, of telescopes called the instruments of transits, of the meridian, and of the parallactic machine; the trigonometrical differential formulæ, which are of so much use in astronomy; the use of the micrometrical rhombus, extended to whatever oblique position; the error arising from refractions in using the astronomical ring for a sundial, and the correction to be made; the appearing and the disappearing of Saturn's ring; the methods of determining the rotation of the sun by means of the spots, proposed formerly by the author, and now perfected; the greatest exactness possible in determining the length of a pendulum oscillating every second of middle time by the comparison of terrestrial and celestial gravity; a compend of astronomy for the use of the marine, containing the elements of the heavenly motions, and of the astronomical instruments to be explained to a prince in the course of one month; a method for determining the altitude of the poles with the greatest exactness, by means of a gnomon alone, where other instruments are not to be had; the determination of the illuminated edge of the moon to be observed on the meridian; a method of using the retrograde return of Venus to the same longitude, for determining the less certain elements of her orbit; a method for correcting the elements of a comet, of which the longitude of the node is given, and the inclination of the orbit has been found nearly; another method for the same purpose, and for finding the elliptical orbit, when the parabolic one does not agree with the observations; a method for correcting the elements of a planet by three observations; the projection of an orbit inclined in the plane of the ecliptic; the projection of an orbit inclined in any other plane; the calculation of the aberration of the stars, arising from the successive propagation of light; some beautiful theorems belonging to triangles, which are of great use in astronomy, reduced to most simple demonstrations.

After having seen the impression of these five volumes finished, Boscovich left Bassano, made an excursion to Rome, and visited his old friends there and in other places of Italy. He then took up his abode at Milan, and applied to the revising of some of his old works,

and to the composing of new ones. He set himself particularly to prepare annotations and supplements to the remaining two volumes of Stay's Modern Philosophy, which he had not had time to publish sooner, and which he lived not to publish.

He was happy at Milan in the neighbourhood of Brera, where was his favourite observatory; and in the company of many friends, who were become the more dear to him by his long absence from them. But he began to consider, with grief, that his two years of absence were drawing to an end. He was very unwilling to leave Italy and return to France. He thought of applying for a prolongation of his absence; he thought of making interest at the Imperial court for some honourable commission, which might be a pretext to him for remaining at Milan: but he was afraid that the proposal of never returning to France might appear indelicate and ungrateful to a nation from which he was receiving considerable pensions. He apprehended that those persons at Paris who had before opposed him, would take occasion to tax him with ingratitude, and that hence his reputation would be tarnished. These, and other such thoughts, occasioned a great perplexity of mind, which was followed by a deep melancholy; and this could not be alleviated by the advice and comfort of his friends, because by degrees he became incapable of hearing reason, his ideas being quite confused, and his imagination disordered. To this disagreeable change the state of his health perhaps contributed. A gout had been wandering for some time through his body, and he had caught a severe cold; nor would he admit of medical assistance, of which he had always been very diffident. It may also be that his long and intense application had hurt the organs of the brain, which in some manner are subservient to the use of reason as long as the soul is united to the body. Be that as it will, during the last five months of his life, this great man, who had been so far superior in reasoning to his ordinary fellow-creatures, was much inferior to every one of them who is endued with the right use of the understanding. He had indeed some lucid intervals, and once there were hopes of a recovery; but he soon relapsed, and an imposthume breaking in his breast, put an end to his mortal existence. He died at Milan on the 13th of February 1787, in the 76th year of his age.

He was tall in stature, of a robust constitution, of a pale complexion. His countenance was rather long, and was expressive of cheerfulness and good humour. He was open, sincere, communicative, and benevolent. His friends sometimes regretted that he appeared to be too irritable, and too sensible of what might seem an affront or neglect, which gave himself unnecessary uneasiness. He was always unstained in his morals, obedient to his superiors, and exact in the performance of all Christian duties, as became a Catholic priest, and in the observance of the particular rules of his order. His great knowledge of the works of Nature made him entertain the highest admiration of the power and wisdom of their Creator. He saw the necessity and advantages of a divine revelation, and was sincerely attached to the Christian religion; having a sovereign contempt of the presumption and foolish pride of unbelievers, and being fully persuaded that we cannot make a more noble use of our understanding than by subjecting it humbly to the authority of the Supreme Being, who knows num-

berless

Boscovich. berless truths far beyond the utmost limits of our narrow comprehension, and who may justly require our belief of any of them that he sees fit to propose to us.

The death of our philosopher, who truly deserved that name, was heard with regret by the learned through Europe, and more than ordinary respect has been paid to his memory. At Ragusa funeral exequies

were performed for him with great solemnity by order of the senate, who assisted at them in a body; on which occasion an eloquent oration in praise of him was pronounced. By a decree of the same senate, a Latin inscription to his honour, engraved on marble, was placed in the principal church of their city. Of this inscription the following is a copy :

Boscovich.

BOSCOVICHII ELOGIUM RAGUSÆ,
Marmore Insculptum.
ROGERIO. NICOLAI. F. BOSCOVICHIO,
Summi. Ingenii. Viro. Philosopho. Et. Mathematico. Præstantissimo
Scriptori. Operum. Egregiorum
Res. Physicas. Geometricas. Astronomicas
Plurimis. Inventis. Suis. Auctas. Continentium
Celebriorum. Europæ. Academiæ. Socio
Qui. In. Soc. Jesu. Cum. Effet. Ac. Romæ. Mathesim. Profiteretur
Benedicto. XIV. Mandante
Multo. Labore. Singulari. Industria
Dimensus. Est. Gradum. Terrestris. Circuli
Boream. Versus. Per. Pontificiam. Ditionem. Transeuntis
Ejusdemque. Ditionis. In. Nova. Tabula. Situs. Omnes. Descripsit.
Stabilitati. Vaticano. Tholo Reddendæ
Portubus. Superi. Et. Inferi. Maris. Ad. Justam. Altitudinem. Redigendis
Restagnantibus. Per. Campos. Aquis. Emittendis. Commonstravit. Viam
Legatus. A. Lucensibus. Ad. Franciscum. I. Cæsarem. M. Etruriæ. Ducem
Ut. Amnes. Ab. Eorum. Agro. Averterentur. Obtinuit
Merito. Ab. Iis. Inter. Patricios. Cooptatus
Mediolarum. Ad. Docendum. Mathematicas. Disciplinas. Evocatus
Braidensem. Extruxit. Instruxitque. Servandis. Astris. Speculam
Deletæ. Tum. Societati. Sæ. Superstes
Lutetiæ. Parisiorum. Inter. Galliæ. Indigenas. Relatus
Commisum. Sibi. Perficiendæ. In. Usus. Maritimos.
Opticæ. Munus. Adcuravit
Ampla. A. Ludovico. XV. Rege. Xmo. Attributa. Pensione
Inter. Hæc. Et. Poësim. Mira. Ubertate. Et. Facilitate. Excoluit
Doctas. Non. Semel. Suscepit. Per. Europam. Perigrinationes
Multorum. Amicitias. Gratia. Virorum. Principum. Ubique. Floruit
Ubique. Animum. Christianarum. Virtutum
Veræque. Religionis. Studiosum. Præ-se-tulit
Ex. Gallia. Italiam. Revivens. Jam. Senex
Cum. Ibi. In. Elaborandis. Edendis. Postrenis. Operibus
Plurimum. Contendisset. Et. Novis. Inchoandis. Ac. Veteribus. Absolvendis
Sese. Adcingeret
In. Diurnum. Incidit. Morbum. Eoque. Obiit. Mediolani
Id. Feb. An. MDCCLXXXVII. Natus. Annos LXXV. Menses IX. Dies II.
Huic. Optime. Merito. De. Republica. Civi
Quod. Fidem. Atque. Operam. Suan. Eidem. Sæpe. Probaverit
In. Arduis. Apud. Exteras. Nationes
Bene. Utiliterque. Expediendis. Negotiis
Quodque. Sui. Nominis. Celebritate. Novum. Patriæ. Decus. Adtulerit
Poit. Funcbrem. Honorem. In. Hoc. Templo. Cum. Sacro. Et. Laudatione
Publice. Delatum
Ejusdem. Templi. Curatores
Ex. Senatus. Consulto.
M. P. P.

This inscription was composed by his friend and countryman the celebrated poet Benedict Stay. Zamagna, another of his countrymen, who had likewise been his fellow-jesuit, published a panegyric on him in elegant Latin. A short encomium of him is to be found in the *Estratto della Letteratura Europea*; and another, in form of a letter, was directed by M. de la Lande to the Parisian journalsts, and by them given to the public. A

more full elogium has been written by M. Fabroni; and another is to be met with in the journal of Modena; a third was published at Milan by the Abbate Ricca; and a fourth at Naples by the Dr Julius Bajamonti, of which a second edition was made in the year 1790. Of this last chiefly use has been made here.

But what must secure to Boscovich the esteem of posterity are his works, of the greater part of which we have:



Boscovich. have already taken notice. We have mentioned, 1. His Elements of Mathematics, with his Treatise on Conic Sections; 2. His many dissertations published during his professorship in the Roman college; 3. His account of his Survey of the Pope's Estate; 4. His Theory of Natural Philosophy; 5. His Poem on the Eclipses; 6. His five volumes printed at Bassano.

To these we may add his hydrodynamical pieces. He had made a particular study of the force of running water, and of its effects in rivers; and he was often consulted concerning the best means to prevent rivers from corroding their banks, and from overflowing the neighbouring plains, which often happens in Italy, where the Alps and Apennines pour down so many impetuous streams. He gave a writing on the damages done by the Tiber at Porto Felice; another on the project of turning the navigation to Rome from Fiumicino to Maceræse; a third on two torrents in the territory of Perugia; a fourth on the bulwarks on the river Panaro; a fifth on the river Sidone, in the territory of Placentia; a sixth on the entrance into the sea of the Adige. He wrote other such works on the bulwarks of the Po; on the harbours of Ancona, of Rimini, of Magna Vacca, and Savona, besides others, almost all which were printed. He had likewise received a commission from Clement XIII. to visit the Pomptin lakes, on the draining of which he drew up his opinion in writing, to which he added further elucidations at the desire of Pius VI. On these occasions he shewed how useful philosophy may be to the public; and of this he gave another proof when it was referred entirely to his judgement to determine whether or not the cupola of the cathedral of Milan could bear the weight of a very high spire, which it was proposed to raise on it, and which was actually erected according to his directions.

His application to abstruse studies did not hinder him from paying some attention to what is more pleasant. We have seen that he was a poet: he was also well acquainted with history, and particularly with that of the Greeks and Romans, and with their antiquities. He wrote a dissertation on an ancient villa discovered in his time upon the Tusculan Hill, and on an ancient dial found there; which dissertation was published at Rome in a literary journal. He wrote likewise three letters on the obelisk of Cæsar Augustus, two of which were printed with his own name, and the third under the name of another.

Besides all these works that were given to the public in his lifetime, many writings of his remained in manuscript in the hands of different persons, and particularly with his friend M. Gaetani, and many more with Count Michael de Sorgo, a Ragusan senator, who inherited all his papers that were in his own hands at his death. These, it is hoped, have either been already sent to the press or will be so; as nothing came from the pen of Boscovich which was not useful and deserving to see the light.

IT now remains that we give an account of his THEORY OF NATURAL PHILOSOPHY; and in doing this we shall, in the *first* place, lay before our readers a view of this system. We shall, in the *second* place, relate, from what principles and by what steps it was de-

duced. We shall, *thirdly*, take notice of the principal objections made to it, and subjoin the author's answers to the same. We shall, *finally*, shew how happily it may be applied to explain the general properties of matter, as well as the particular qualities of all the classes of bodies, which have been examined according to what it teaches.

I. In this system, therefore, the whole mass of matter, of which all the bodies of the universe are composed, consists of an exceeding great, yet still finite number of simple, indivisible, inextended, atoms. These atoms are endued with *repulsive* and *attractive* forces, which vary and change from the one to the other, according to the distance between them, in the following manner: In the least and innermost distances they repel one another; and this repulsive force increases beyond all limits as the distances are diminished, and is consequently sufficient for extinguishing the greatest velocity, and for preventing the contact of the atoms. In the sensible distances, this force is *attractive* and decreases, at least sensibly, as the squares of the distances increase, constituting universal gravity, and extending beyond the sphere of the most distant comets. Between this innermost repulsive force and the outermost attractive one, in the insensible distances, many varieties and changes of the force, or determination to motion, take place: for the repulsive force decreases as the distance increases. At a certain distance it comes to vanish entirely; and, when that distance is increased, attraction begins, increases, becomes less, vanishes; and the distance becoming greater, the force becomes repulsive, increases, lessens, and vanishes as before. Many varieties and changes of this kind happen in the insensible distances, sometimes more rapidly, sometimes more slowly, and sometimes one of the forces may come to nothing, and then return back to the same without passing to the other. For all this there is full room in the distances that are insensible to us, seeing the least part of space is divisible *in infinitum*. Besides these repulsive and attractive forces, our atoms have that *vis inertia* which is admitted by almost all modern philosophers. These atoms, endued with these forces, constitute the whole substance of Boscovich's system; which, however simple and short it may appear to be, has numberless and very wonderful consequences, as we shall see afterwards. But, that a more clear idea of the whole theory may be easily formed, we shall make use of a geometrical figure well accommodated to that purpose. The right line CAC is an axis, from which, in the point A, is drawn the right line AB at right angles. AB is considered as an *asymptote*; on each side of which the two curves, quite similar and equal, DEFGHIKLMNOPQRSTVU on the one side, and D'E'F'G' on the other, are placed. Now, if ED be supposed to be *asymptotical*, and be extended, it will still approach to BA, but will never come to touch it. This curve ED approaches to the axis C'C, comes to it in E, cuts it and departs to a certain distance in F, after which it again approaches the same axis and cuts it in G. In like manner it forms the arches GHI, IKL, LMN, NOP, PQL. At last it goes on in T p s V, which is asymptotical, and approaches to the axis; so that the distances from it are in a duplicate reciprocal proportion of the distances from the right line BA. If from any points of the axis, as from *a, b, d*, we raise the per-

Boscovich's System of Natural Philosophy.

View of Boscovich's system of natural philosophy.

The whole theory expressed by a geometrical curve. Plate VI. fig. 6.

Buffovich's
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Philosophy.

perpendiculars $a g, b r, d h$, the segments of the axis $A a, A b, A d$, are called *abscissæ*, and represent the distances of any two points of matter from one another; and the perpendiculars $a g, b r, d h$, are called *ordinates*, and exhibit the repulsive or attractive force, according as it lies on the same side with D , or on the other side of the axis.

Now it is evident that, in this form of the curve line, the *ordinate* $a g$ will be increased beyond whatever limits, if the abscissæ $A a$ be lessened likewise beyond whatever limits; that if this abscissæ be increased to $A b$, the *ordinate* will be lessened, and will pass into $b r$, which will still be lessened as it approaches from b to E , where it will come to nothing; that then, the axis being increased to $A d$, the *ordinate* will change its direction into $b h$, and, on the opposite side, will increase at first to F , then it will decrease through $i l$ as far as G , where it will again vanish, and again change its direction in $m n$ to the former; and that, in the same manner, it will vanish and change its directions in all the sections l, L, N, P, R , until the *ordinates* $o p, v s$, become of a constant direction, and decrease, at least sensibly, in a reciprocal duplicate proportion of the abscissæ $A o, A v$. Wherefore, it is manifest, that by such a curve are expressed our forces; at first *repulsive* and increasing beyond all limits, the distances being lessened in like manner, and which decrease, the same distances being augmented; then vanish, change their direction, and become *attractive*; vanish again, and become *repulsive*; till at last, at sensible distances, they remain on the side opposite to D , and are *attractive* in a duplicate reciprocal proportion of the distances.

We may also observe that the *ordinates* may increase or decrease rapidly, as in $y v, z t$, or slowly, as in $v x, z c$; and, consequently, that the forces may increase or decrease in like manner. We may add, that the curve may return back without intersecting, or even touching, the axis, as in f , and may return after having touched the same axis.

Although this curve expresses very clearly the *repulsive* and *attractive* forces of our system, yet, at first sight, it may appear to be a complicated irregular line. But the author shews that his curve is uniform and regular, and may be expressed by one uniform algebraical equation; which it will be necessary for us to consider, in order to give satisfaction to our readers, and to do justice to the theory.

Wherefore, from what we have seen, the curve must have the following six conditions: *1st*, It must be regular and simple, and not composed of an aggregate of arches of different curves. *2^{dly}*, It is necessary that it cut the axis $C'AC$ in certain given points only, at two equal distances on each side AE', AE, AG', AG , and so on. *3^{dly}*, That to every *abscissæ* an *ordinate* correspond. *4^{thly}*, That if we take equal *abscissæ* on each side of A , they have equal *ordinates*. *5^{thly}*, That the right line AB be an *asymptote*, the area $BAED$ being asymptotical, and consequently infinite. *6^{thly}*, That the arches terminated by any two intersections may be varied at pleasure, and recede to any distance from the axis $C'AC$, and approach at pleasure to whatever arches of whatever curves, cutting them, touching them, or osculating them, in any place and manner.

In order to find an algebraical formula expressing the nature of a curve line that would answer all these

six conditions, let us call the ordinate y , the abscissæ x , and let it be made $x x = z$. Then let us take the values of all the abscissæ AE, AG, AI , &c. with the negative sign, and let the sum of the squares of all these values be called a , the sum of the products of every two squares b , the sum of the products of every three, c , and so on; and let the product of all of them be called f , and the number of the same values m . All this being supposed, let it be made $z^m + a z^{m-1} + b z^{m-2} + c z^{m-3}$ &c. $+ f = P$. If we suppose P equal to nothing, it is clear that all the roots of that equation will be real and positive; that is, the squares only of the quantities AE, AG, AI , &c. which will be the values of z ; and therefore, as it is $x = \pm \sqrt{z}$, because it is $x x = z$, it is likewise clear that the values of x will be both AE, AG, AI , positive, and $A'E', A'G'$, &c. negative.

This being done, let any quantity be multiplied by z , providing it hath no common divisor with P , left z vanishing, it likewise might vanish; and having made x an infinitesim of the first order, it may become an infinitesim of the same, or of a lower order, as will be whatever formula $z^r + g z^{r-1} + b z^{r-2}$ &c. $+ l$; which, being supposed equal to o , may have as many imaginary, and as many and whatever real roots, providing none of them be those of AG, AE, AI , &c. either positive or negative. If then the whole formula be multiplied by z , let this product be called Q .

If we make $P - Q f = o$, this equation will satisfy the five first conditions above mentioned; and the value of Q being properly determined, the sixth condition also may be complied with.

For, in the first place, seeing the value P and Q are made equal to o , they have no common root, and therefore no common divisor. Hence this equation cannot be reduced to two by division; and therefore it is not composed of two equations, but is simple, and therefore exhibits one simple continued curve, which is not composed of any others; which is the first condition.

Secondly, The curve thus expressed will cut the axis $C'AC$ in all the points E', G, I , &c. and $G', I, &c.$ and in them only: for it will cut that axis only in those points in which $y = o$, and in all of them. Moreover, where it will be $y = o$, it will also be $Q y = o$; and therefore, because of $P - Q y = o$, it will be $P = o$. But this will happen only in those points in which z will be one of the roots of the equation $P = o$; that is, as we have seen above, in the points E, G, I , or $E', G', &c.$: wherefore, only in those points will y vanish, and the curve cut the axis. Again, that the same curve will cut it in all these points, is clear from this, that in them all it will be $P = o$. Wherefore it will likewise be $Q y = o$; but it will not be $Q = o$, seeing there is no common root of the equations $P = o$ and $Q = o$: it must therefore be $y = o$, and the curve will cut the axis: and thus the second condition is satisfied.

Besides, whereas it is $P - Q x = o$, it will be $y = \frac{P}{Q}$. the abscissæ x being, however, determined, we will have a certain determinate quantity for z ; and thus P, Q , will be determined, and the only two of the kind. Wherefore y also will be sole and determined; and therefore to every abscissæ z , one only ordinate y will correspond. This is the third condition.

Again, whether x be assumed positive or negative, pro-

3
The simplicity of this curve proved.

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providing it be of the same length, still the value $z = xx$ will be the same, and therefore the values of both P and Q will be the same: wherefore y will still be the same. Taking, therefore, equal abscisses z on both sides of A, the one positive, the other negative, they will have equal corresponding ordinates. This is the fourth condition.

If x be lessened beyond all limits, whether it be positive or negative, z likewise will be lessened beyond all limits, and will become an infinitesim of the second order: wherefore, in the value P, all the terms will decrease in infinitum, except in y, because all the rest besides it are multiplied by z; and thus the value P will be as yet finite. But the value Q, which has the formula multiplied by z, will be lessened in infinitum, and will be an infinitesim of the second order: therefore $\frac{P}{Q}$

$= y$ will be augmented in infinitum, so as to become an infinite of the second order. Wherefore the curve will have the right line AB for an asymptote, and the area BAED will increase in infinitum: and if the ordinate y be assumed positive on the side AB, and express repulsive forces, the asymptotic arch ED will lie on the same side AB. This is the fifth condition.

Now the value Q can be varied in infinite manners; so that still the conditions for which it was assumed may be fulfilled; and therefore the arches of the curve intercepted by the intersections may be varied in infinite manners; so that the first five conditions of the curve may be implemented: whence it follows that they may be so varied that the sixth condition may also be answered.

For if there be given, however many, and whatever arches of whatever curve, providing they be such that they recede always from the asymptote AB, and thus no right line parallel to that asymptote cut these arches in more than one point, and in them let there be taken as many points as you please, and as near one another; it will be easy to assume such a value of P, that the curve shall pass through all these points, and the same may be varied infinitely; so that still the curve will pass through all the same points.

Let the number of points assumed be what you please $= r$, and, from every one of such points, let right lines be drawn parallel to AB, as far as the axis C'AC, which must be the ordinates of the curve that is sought; and let the abscisses from A to the said ordinates be called M¹, M², M¹, &c. and the ordinates N¹, N², N³, &c. Let there now be taken a certain quantity $Az^r + Bz^{r-1} + Cz^{r-2} + Gz$, and let this quantity be supposed equal to R. Then let another such quantity T be assumed, so that z vanishing, whatsoever term of it may vanish, and so that there be no common divisor of the value of P, and of the value of R + T: which may be easily done, seeing all the divisors of the quantity P are known. Let it now be made $Q = R + T$, and then the equation of the curve will be $P - Ry - Ty = o$. After this, let there be put in the equation M₁, M₂, M₃, successively for x, and N₁, N₂, N₃, &c. for y; we will have a number of equations equal to r, which will contain the values of A, B, C, . . . G, each of them of one dimension, in number likewise equal to r; and, besides, we will have the given values of M₁, M₂, &c. N₁, N₂, N₃, &c. and the arbitrary values which in T are the coefficients of z.

By these equations, which are in number r, it will be easy to determine the values A, B, C, . . . G, which are likewise in number r, assuming in the first equation, according to the usual method, the value A, and substituting it in all the following equations; by which means the equations will become $r-1$. These, again, by throwing out the value B, will be reduced to $r-2$, and so on until we come to one only; in which the value Q being determined by means of it, going back, all the preceding values will be determined, one by each equation.

The values A, B, C, . . . G, being in this manner determined, in the equation $P - Ry - Ty = o$, or $P - Qy = o$, it is clear that the values M₁, M₂, M₃, &c. being successively put for x, the values of the ordinate y must successively be N₁, N₂, N₃, &c.; and, therefore, that the curve must pass through these given points in those given curves; and still the value Q will have all the preceding conditions. For z being lessened beyond whatever limits, every one of its terms will be lessened beyond whatever limits, seeing all the terms of the value of T are lessened which were thus assumed, and likewise the terms of the value R are lessened, which are all multiplied by z; and, besides this, there will be no common divisor of the quantities P and Q, seeing there is none of the quantity P and R + T.

But if two of the nearest of the points assumed in the arches of the curves, on the same side of the axis, be supposed to accede to one another beyond whatever limits, and at last to coincide, which will be done by making two M equal, and likewise two N equal; then the curve sought will touch the arch of the given curve; and if three such points coincide, they will osculate it: nay, as many points as we please may be made to meet together where we please; and thus we may have osculations of what order we please, and as near one another as we please, the arch of the given curve approaching as we please, and at whatever distances we please, to whatever arches of whatever curves, and yet still preserving all the six conditions required for expressing the law of the repulsive and attractive forces. And whereas the value of T can be varied in infinite manners, the same may be done in an infinite number of ways; and therefore a simple curve, answering the given conditions, may be found out in an infinite number of ways. Q. E. F.

What we have said will, we hope, satisfy our readers, and especially those of them who are in the least acquainted with high geometry, that Boscovich's curve is simple, regular, and uniform; and that therefore the law of repulsive and attractive forces, expressed by it, is simple and regular.

II If this system were a mere hypothesis, it would still be very ingenious, and, from what we shall say afterwards, would still be well adapted for explaining the phenomena of nature. But its author is far from looking upon it as an arbitrary supposition; he assures us that he was led to it by a chain of strict reasoning, from evident principles. We shall now give an abridgement of that reasoning from his Dissertations on the Law of Continuity, and from his Theory of Natural Philosophy.

He tells us, then, that in the examination of Leibnitz's opinion of the vires vivæ, he came to consider the collision of bodies, and took for example two equal bodies A proceeding with six degrees of velocity, and B following with the velocity of 12: after the collision,

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the theory

Boscovich's System of Natural Philosophy. 9. Now, in the moment of collision, it either happens that A passes abruptly from the velocity 6 to the velocity 9, without passing through the velocity 7 and 8, and B passes from 12 of velocity to 9, without passing through 11 and 10; or else there must be some cause which accelerates the one and retards the other before they come to contact. In the first case, the law of continuity is broken; in the second, immediate contact of bodies would be rejected. Maclaurin saw this difficulty, and mentioned it in his work on *Newton's Discoveries*, l. i. c. 4. He, not having courage to recede from the common opinion, allowed a breach, in such cases, of the law of continuity; but Boscovich maintains the universality of the law of continuity; and holds that no bodies touch one another really and mathematically, but only physically and sensibly to us.

5
The law of continuity proved

The law of continuity is that by which variable quantities, passing from one magnitude to another, pass through all the intermediate magnitudes, without ever abruptly passing over any of them. This law Boscovich proves to be universal, in the first place, from induction. Thus we see that the distances of two bodies can never be changed without their passing through all the intermediate distances. We see the planets move with different velocities and directions; but in this they still observe the law of continuity. In heavy bodies projected, the velocity decreases and increases through all the intermediate velocities: the same happens with regard to elasticity and magnetism. No body becomes more or less dense without passing through the intermediate densities. The light of the day increases in the morning and decreases at night through all the intermediate possible degrees. In a word, if we go through all nature, we shall see the law of continuity strictly take place, if all things be rightly considered. It is true, we sometimes make abrupt passages in our minds; as when we compare the length of one day with that of another immediately following, and say that the second is two or three minutes longer or shorter than the former, passing all at once, in our way of speaking, round the globe; but if we take all the longitudes, we shall find days of all the intermediate lengths. We likewise sometimes confound a quick motion with an instantaneous one: thus, we are apt to imagine that the ball is thrown abruptly out of the gun; but, in truth, some space of time is required for the gradual inflammation of the powder, for the rarefaction of the air, and for the communication of motion to the ball. In like manner, all the objections made against the law of continuity may be solved to satisfaction.

6
A breach of this law impossible.

But however strong this argument from judgment may appear to be, yet Boscovich goes farther, and maintains, that a breach of this law, in the proper cases, is metaphysically impossible. This argument he draws from the very nature of continuity. It is essential to continuity that, where one part of the thing continued ends and another part begins, the limit be common to both. Thus, when a geometrical line is divided into two, an indivisible point is the common limit to both: thus time is continued; and therefore where one hour ends, another immediately begins, and the common limit is an indivisible instant. Now, as all variations in variable quantities are made in time, they all partake of its continuity; and hence none of them can hasten by an

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abrupt passage from one magnitude to another, without passing through the intermediate magnitudes. As we cannot pass from the sixth hour to the ninth without passing through the seventh and eighth; because, if we did, there would be a common limit between the sixth hour and the ninth, which is impossible: so likewise you cannot go from the distance 6 to the distance 9 without passing through the distances 7 and 8; because, if you did, in the instant of passage you would be both at the distance 6 and at the distance 9, which is impossible. In like manner, a body that is condensed or rarefied cannot pass from the density 6 to the density 9, or vice versa, without passing through the densities 7 and 8; because, in the abrupt passage, there would be two densities, 6 and 9, in the same instant. The body must pass through all the intermediate densities. This it may do quickly or slowly, but still it must evidently pass through them all. The like may be said of all variable quantities; and thence we may conclude, that the law of continuity is universal.

But, in creation, is there not an instance of an abrupt passage from non-existence to existence? No, there is not; because before existence a being is nothing, and therefore incapable of any state. In creation, a being does not pass from one state to another abruptly; it passes over no intermediate state: it begins to exist and to have a state, and existence is not divisible. Do we not, at least, allow of an abrupt passage from repulsive to attractive forces in our very theory itself? We do not. Our repulsive forces diminish, through all the intermediate magnitudes, down to nothing; through which, as a limit, they pass to attraction. In the building of a house or ship, neither of them is augmented abruptly; because the additions made to them are effected solely by a change of distances between the parts of which they are composed: and all the intermediate distances are gone through. The like may be said of many other such cases; and still the law of continuity remains firm and constant.

7
Objections to this law answered.

Let us now apply this doctrine to the case above mentioned of the collision of two bodies. We say that the body B cannot pass from the velocity 6 to the velocity 9 without passing through the velocities 6 and 7; because if it did, in the moment of contact of the two superficies it would have the velocities 6 and 9. Now a body cannot have two velocities at the same instant. For if it had two actual velocities at the same time, it would be in two different places at the same time: if it had two different potential velocities or determinations to a certain velocity, it would be capable of being, after a given time, in two places at once—both which are impossible. It is therefore necessary that it go through the velocities 7 and 8, and through all the parts of them. What we have said of the bodies A and B may be said universally of all bodies. Therefore no two bodies in motion can come to immediate contact; but their velocities must undergo the successive necessary change before contact. And as the velocity to be extinguished may be increased beyond all limits, an adequate cause to effect this extinction must be admitted.

8
Impossibility of contact between bodies.

This naturally leads us to the interior repulsive forces of our system; for the cause retarding the one body and accelerating the other must be a force, because by this we mean a determination to motion; and it must be repulsive, because it acts from the body; and it must increase

9
Repulsive forces

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System of
Natural
Philosophy.

10
In extended
atoms.

increase beyond all limits, seeing the velocity of the incurring bodies may be increased beyond all limits. It must likewise be mutual, because action and reaction are always equal, as may be proved by induction.

From these repulsive forces Boscovich deduces the inextension of his atoms: for this repulsion being common to all matter, must cause a perfect simplicity in the first elements of body. If these elements were extended, and consequently compounded of particles of an inferior order, these particles might possibly be separated, and then they might meet, and an abrupt passage from one velocity to another might take place, which we have excluded from nature by induction, and by a positive argument.

Besides this, by rejecting the extension of the first elements of matter, we get rid at once of all the difficulties arising from continued extension in body, which have always perplexed the philosophers, and have never been satisfactorily explained. If the elements of matter are extended, each of them may be divided *in infinitum*, and each part may still be divided *in infinitum*. Can this division be actually made by the power of God or not? Can there be one *infinite* in number greater than another? Can there be a *compound* without a *simple* of the same kind? These difficulties regard not space, which is no real being; but they would regard matter if it had continued extension. All these perplexities are removed by maintaining, as Boscovich does, that the first elements of bodies are perfectly simple, and therefore inextended (A).

11
Attractive
forces.

With regard to the exterior attractive forces of our system, there can be no question; seeing they constitute universal gravity, the effects of which we see and feel every day. But between the interior repulsive and exterior attractive forces we must admit many transitions from repulsion to attraction, and from attraction back to repulsion, in insensible distances, which are indicated to us by cohesion, fermentation, evaporation, and other phenomena of nature. And thus we have given, in short, Boscovich's proofs of his whole system.

12
Objections
to the sys-
tem an-
swered.

III. This system has been well received by the learned in Europe, and has contributed much to render its author famous; yet many objections against it have been proposed. Some are startled at the rejection of all immediate contact between bodies: and indeed Boscovich is perhaps the first of mankind who advanced that opinion; but he allows that bodies approach so near to one another, as to leave no sensible distance between them; and his repulsive forces make the same impression on the nerves of our senses as the solid bodies could do. And therefore this opinion of his, however new, is nowise contrary to the testimony of our senses. He only removes a prejudice which was before universal.

Some say, that they cannot even form an idea of an inextended atom, and that Boscovich reduces all matter to nothing: but certainly extension is not necessary

for the essence of a *being*, as must be allowed by all those who hold that spirits are inextended. Because all the bodies that fall under our senses are extended, we are apt to look upon extension as essential to matter: but this error may be corrected by reflection, and an idea of an inextended atom may be formed, by considering the nature of a mathematical point, which is the limit of any two contiguous parts of a line.

Others again have said, that if the elements of matter were void of extension, there would be no difference between body and spirit. But the difference between body and spirit does not consist in the having or not having extension; but in this, that the atoms of matter are endued with repulsive and attractive forces, which spirit has not; and spirit has a capacity of thought and volition which bodies have not.

We may here observe, that among the ancients Zeno, and among the moderns Leibnitz, held, that the first principles of matter are inextended points. But both held this opinion with the inconsistency, that they maintained the continued extension of bodies, without ever being able to shew how continued extension could arise from inextended elements.

It has been objected likewise, that our repulsive and attractive forces are no better than the occult qualities of the Peripatetics. The like objection has been made to Newton's attraction: but the answer is easy. We observe the effects, and take notice of them: for them we must admit an adequate cause, without being able to determine, whether that cause is an immediate law of the Creator, or some mediate instrument that he makes use of for that purpose.

Some are unwilling to give up the idea of motion occasioned by immediate impulse: but can they show a good reason why *some distance* may not occasion motion as well as *no distance*? These are the principal objections that have been made against the Boscovichian system.

IV. Before we proceed to the explication of phenomena by means of our theory, we must advert, that in the curve expressing this theory, the abscisses denote the distances between the atoms that are under consideration; the ordinates give the present *force*, and the area between any two of these ordinates gives the square of the velocity generated between them; the arches are either repulsive or attractive, according as they fall upon the same side with the asymptotic curve EG, or on the opposite side.

We must, in the next place, consider the passages from one side of the axis to the other. Sometimes the passage is from repulsion to attraction, at other times from attraction to repulsion. The first are called *limits of cohesion*, because a particle removed from that limit returns back to it; because if it is removed to a greater distance it is attracted back, and if it is removed nearer it is repelled back. The second are called *limits of non-cohesion*; &c.

(A) If a particle of matter is not extended, in what respect does it differ from a point of space? Says Boscovich, it is endowed with attractive and repulsive forces. What is this *it* before it is thus endowed? Does it then differ from a point of space? We can form no notion of any such difference. But a point of space, considered as an individual, is distinguished from another individual only by its situation; it is therefore immoveable, but matter is moveable. Have these forces, then, which make matter an object of sense, any substratum, any thing in which they are inherent as qualities? What are the things which these qualities distinguish from each other as individuals?

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13
Observations
regard to
the curve

14
Limits of
cohesion
&c.

Boscovich's *cohesion*; because a particle removed thence to a greater distance is repelled still further, and if removed nearer it is attracted still nearer. Of the first kind are E, I, N; of the second are G, L. Likewise, when the curve touches the axis, it may either be an attractive part of the curve, or a repulsive part. These limits may be nearer one another, or farther away; and the limits of cohesion may be stronger or weaker, according as the forces near them are greater or less.

Boscovich considers minutely the effects of these varieties of limits and forces; first with regard to two points, then with regard to three and four, demonstrating the great variety of forces that may arise from these various combinations, and shewing how from simple atoms a great variety of bodies may be formed. He particularly proves, that, from the various position of the atoms, they may either always repel or always attract other atoms, or do neither. Four atoms may form a pyramid, eight may form a cube, and so on, in regular or irregular figures. Particles of the lowest order may compose particles of a second order, these of a third, and so on. This he exemplifies by a library, in which the letters of the books should be composed of small points, placed so near one another as that their distance could not be perceived without the help of a microscope. Here the letters will be composed of points, the words of letters, and all the variety of books on different subjects, and in different languages, would be composed of words. In like manner, he says, his atoms may compose particles, these may compose others of different orders, of which may be formed various bodies, animal, vegetable, air, fire, water, earth, whole planets, central bodies, the whole universe.

But to be more particular, our author proceeds to apply his system to mechanics, and demonstrates, with his usual accuracy and originality, what regards the centre of gravity, action and reaction, the collision of bodies, the centre of equilibrium, and of oscillation. Of these subjects he treats in the second part of his *Theoria*; to which we must refer our learned readers, as it cannot be easily abridged.

In the third part of the same work he proceeds to account for the general properties of matter, beginning with *impenetrability*. This naturally flows from the interior repulsive forces, which prevent the compenetration of any two points. Besides, as the least part of space is divisible *in infinitum*, it is infinitely improbable that any two points should ever meet, seeing they have an infinite number of other lines in which they can move, besides the one that would join them. But an apparent compenetration might take place, if one body should meet another with so great a velocity as not to give time to the repulsive forces to exert their action. Thus an iron ball may pass swiftly near a strong magnet, without being sensibly attracted by it, which it would be if it moved more slowly. Thus a ball from a gun passes through a piece of wood so quickly as to make only a passage for itself, without breaking the neighbouring parts, which it would do were its motion more slow. Of this kind of compenetration we have a resemblance in *light* passing through pellucid bodies.

Cohesion has never been well accounted for by any philosopher before Boscovich. From his system it follows naturally, as we have seen in speaking of the limits

of cohesion; for when two atoms are placed in a limit of that kind, they necessarily cohere more or less strongly, according as that limit is stronger or weaker. From the cohesion of the atoms arises the cohesion of compounded particles, and consequently of sensible bodies.

From the cohesion of particles arises the extension of bodies; because there must always be space between the particles. However, it is evident that this extension is not formed of a continuity of matter; though it may appear to be so to our senses, which cannot perceive the small intermediate distance between the parts of some bodies, and much less the distances between the simple elements of which they are composed.

Extension of bodies involves *figurability*; because every extended body must be surrounded by some superficies of a certain figure; but the superficies of bodies can never be accurately determined, upon account of the inequalities in all surfaces. We take, however, that figure for the true one which the body appears to come nearest. Thus we call the earth a globe, notwithstanding the hills and valleys that are on it.

Under the same figure, and of the same magnitude, there may be contained very different quantities of matter. Hence we come to the consideration of *density*. That body is most dense which contains in the same space the greatest number of atoms, and *vice versa*.

This density may be increased beyond any given limits by the nearer approach of the atoms to one another. Hence a body of any given magnitude, however small, may come to be divisible beyond any given limits.

Mobility, which is likewise reckoned among the general properties of body, is essential to our system, seeing an essential part of it consists in *forces*, which are determinations to motion, at least in certain distances.

Universal gravity in sensible distances is likewise a branch of our theory. On which subject it may be observed, that perhaps our curve, after it has extended beyond the sphere of the comets most distant from the sun, may depart from its asymptotical nature, and approach to the axis, intersect it, and pass to repulsion. This would effectually answer the objection made by some against Newton's attraction, when they allege, that, from his opinion, it would follow, that the fixed stars, and all matter, would be drawn together into one mass. If such a repulsion takes place, it may soon pass again into attraction, and form limits of cohesion; so that our sun may be in such a limit with regard to the fixed stars, and our planetary system make only a small part of the whole universe. And this may suffice concerning the general properties of matter.

Let us now descend to some particular classes of bodies, of which some are fluid, others solid. The parts of fluid bodies are easily separated, and easily moved round one another, because they are spherical and very homogeneous; and hence their forces are directed more to their centres than to one another, and their motions through one another are less obstructed. Between the particles of some of them there is very little attraction, as in fine sand or small grains of seed, which approach much to fluidity. The particles of some others of them attract one another sensibly, as do those of water, and still more those of mercury. This variety arises from the various combinations of the particles themselves, of which we have already taken notice. But in air the

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19 Extension,

20 Figure,

21 Density,

22 Mobility,

23 Gravity,

24 Fluidity,

Boscovich's System of Natural Philosophy. particles repel one another very strongly; and hence comes that great rarefaction, when it is not compressed by an external force. Its particles must be placed in ample limits of repulsion.

25
Solidity,

Solid bodies are formed of parallepipeds, fibres, and of irregular figures. This occasions a greater cohesion than in fluids, and prevents the motion of the parts round one another; so that when one part is moved all the rest follow. Of these bodies some are harder, whose particles are placed in limits which have strong repulsive arches within them; others are softer, whose particles have those arches of repulsion weaker. Some are flexible, the particles of which are placed in limits that have weak arches of repulsion and attraction on each side; and if those arches are short, the particles may come to new limits of cohesion, and remain bent: but if the arches are longer, the former repulsion and attraction will continue to act, and bring back the body to its former position; nay, in doing this with an accelerated velocity, the parts will pass their former limits, and vibrate backwards and forwards, as may be seen in a bended spring. Thus elasticity is accounted for.

26
Softness, flexibility, and elasticity.

27
Viscosity.

Viscous bodies stand in the middle between solid and fluid. Their particles have less cohesion than the first, and more than the second: they stick to other bodies by an attraction which their particles have from their composition. In like manner water itself sticks to some bodies, and is repelled by others. All which arises from the different composition of the particles, which gives a variety of respective forces.

28
Organization.

What appears very wonderful in nature, is the composition of organic bodies. But if we consider that particles may be so formed, that they may repel some and attract others, the whole of vegetation, nutrition, and secretion, may be understood, and follows from our system. And as one particle may attract another in one part only, and repel it in every other situation, hence may be gathered the orderly situation of the particles in many crystallizations. The great variety of repulsive and attractive forces, or limits of cohesion, of the position of atoms, and of combinations of particles, will account for all these phenomena.

29
Chemical operations.

The chemical operations, which are so curious in themselves, and so useful to society, are well explained by Boscovich's system, and serve as a confirmation of its truth. Of this we shall give some instances. When some solids are thrown into some liquids, there happens to be a greater attraction between the particles of the solid and of the liquid than there is between the particles of the solid itself. Hence the particles of the solid are detached and surrounded by the fluid; this mixture retaining the form of globules, and therefore continuing to be fluid. This is called *solution*. But when the solid particles are covered to a certain depth, the attractive forces cease on account of the different distances, and no more of the solid is detached. Then the fluid is said to be *saturated*. If into this mixture another solid be put, the particles of which attract the fluid more strongly, and perhaps at greater distances than the particles of the former; then the fluid will abandon the former and cleave to the latter, dissolving them, and the particles of the former will fall to the bottom in the form of powder, into which they had been reduced by the solution. This separation is called *precipitation*. Perhaps rain arises from a precipitation

of this kind, when the aqueous particles are left by the air, which is more strongly attracted by some other particles floating in the atmosphere.

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Fluids of the same specific gravity are easily mixed; and even though the specific gravity be different, the particles of the one attract those of the other, in such a manner that they seem to form one fluid by a kind of solution. Nay, it happens that two fluids mixed together form a solid, because their particles come to be in the limits of cohesion. They may even occupy less space than they did before, by being attracted into less distances between their parts.

Fermentation is a necessary consequence of our system. For when bodies, whose particles, by the variety of their composition, are endued with different forces, come to be mixed, there must arise an agitation of the parts, and an oscillation among them; sometimes greater, sometimes less, according to the nature of the particles. This agitation is stopped by the expulsion of some particles, by the intrusion of others into vacant spaces, and by the impression of external bodies; but always there is a change in what remains, because there is a new disposition of particles.

Fire consists in a violent fermentation of sulphureous matter, especially when it meets with the matter of light in any quantity. This fermentation agitates strongly the parts of other bodies, separates them from one another, and often throws them into a state of fusion; the cohesion between their parts being broken, and they being thrown into a circular motion. In this state they may be often mixed together, so as to form one body; they may be again separated by the action of the same fire, which evaporates some of them sooner, some later. Hence the art of smelting metals.

30
Fire and lightning, &c.

When, in the agitation occasioned by fire, some of the particles are thrown out into an arch of repulsion, they may fly off and evaporate. Sometimes the whole body may be thrown into a strong repulsion and volatilization, or a sudden explosion take place; when, before the particles are near an equilibrium, a small force may occasion a great change; as the foot of a bird may occasion the fall of a great rock, which was before almost detached from a mountain. In evaporation, the bodies that remain assume a particular figure, as all salts do; and this upon account of their particles having certain parts only that attract one another, and consequently occasion a particular disposition. All these chemical operations evidently prove that there are in nature repulsive and attractive forces between the particles of bodies at small distances: which greatly confirms our whole system.

Boscovich holds, that light is an *effluviu*m, emitted with great velocity from the luminous bodies by a strong repulsion. He explains all the most remarkable properties of this extraordinary matter according to his own principles, and that with great acuteness. On this subject it is observable, that Newton saw the necessity of admitting repulsive forces for the reflexion of light, which extend at some distance from the reflecting surface, and therefore resemble the repulsive forces of our theory.

31
Light.

Our author gives likewise a probable explication of electricity, according to Franklin's ingenious hypothesis, and likewise of magnetism, deducing the whole of the appearances from various attractions and repulsions.

32
Electricity and magnetism.

He

Boscovich's System of Natural Philosophy. He supposes that fire and the electrical fluid differ only in this, that fire is in actual fermentation, and not so the electrical fluid.

33 Sensation. Finally, he explains our bodily sensations, in which he agrees pretty much with other philosophers; excepting in this, that what they attribute to the immediate contact of bodies, or of certain particles emitted from them, he ascribes to attractions and repulsions; which indeed are particularly fit for causing that motion in our nerves, which is supposed to take place in the organs of sensation, and to be thence communicated to the brain.

34 Reconciliation of this with other systems. It is to be observed, that although Boscovich maintains that the very first elements of matter are void of extension; yet he allows, that of these elements, combined in a certain manner, may be formed extended particles of various figures, the parts of which may be so coherent as to be inseparable by any power in nature. By these means the opinion of those philosophers, who are so fond of extended particles, may be in so far gratified. Nay, the Peripatetics may, if they please, adopt Boscovich's inextended atoms for their *Materia Prima* without any inconsistency; and his repulsive and attractive forces may serve for their *substantial forms*. And as God can make impressions on our senses independently of the atoms, their absolute accidents may in some sense be admitted. Nor would some such extraordinary exertions of Divine Power favour idealism in the ordinary course of nature.

35 Especially that of Newton. But what is of more consequence, it is more than probable, that had Newton lived to be acquainted with the Boscovichian theory, he would have paid to it a very great regard. This we may conjecture from what he says in his last question of optics; where, after having mentioned those things which might be explained by an attractive force, succeeded by a repulsive one on a change of the distances, he adds, "And if all these things are so, then all nature will be very simple, and consistent with itself, effecting all the great motions of the heavenly bodies by the attraction of gravity, which is mutual between all those bodies, and almost all the less motions of its particles by another certain attractive and repulsive force, which is mutual between those particles." And a little after, treating of the elementary particles, he says: "Now it seems that these elementary particles not only have in themselves the *vis inertiae*, and those passive laws of motion which necessarily arise from that force, but that they likewise perpetually receive a motion from certain active principles; such as gravity, and the cause of fermentation, and of the cohesion of bodies. And I consider these principles, not as occult qualities, which are feigned to flow from the specific forms of things, but as universal laws of nature, by which the things themselves were formed. For that truly such principles exist, the phenomena of nature shew, although what may be their causes has not as yet been explained. To affirm that every species of things is endued with specific occult qualities, by which they have a certain power, is indeed to say nothing; but to deduce two or three general principles of motion from the phenomena of nature, and then to explain how the properties and action of all corporeal things follow from those principles, this truly would be to have made a great advancement in philosophy, although the causes of those principles were not as yet known.

Boscovich's System of Natural Philosophy. Wherefore I do not hesitate to maintain the above said principles of motion, seeing they extend widely through all nature." From this passage we may safely conclude, that the great British philosopher would have been highly pleased, had he seen all nature so well explained by the one simple law of forces proposed by the Ragu-
san.

36 Comparison of this system to the key of a cypher. Boscovich himself was so fully convinced of the truth of his system, that he was wont to make use of the following comparison: When a letter has been written in occult characters, and we are endeavouring to decypher it, we make various suppositions of alphabets; and when we have found one according to which the whole letter comes to have a reasonable meaning, agreeable to all the circumstances of time, place, persons, and things, we can entertain no doubt of our having discovered the true key of the cypher—so, said he, my system explains so well all the phenomena to which it has been properly applied, that I must flatter myself that I have discovered the true key of nature.

37 Existence of God. The being accustomed to contemplate so deeply the universe and the materials of which it is composed, made Boscovich see most clearly the evident necessity of admitting an all-powerful, intelligent, self-existent Being, for the creation of those materials, and for the arrangement of them into their present beautiful form. He was at a loss to find words strong enough to express his surprise, that there should be any man, not to say any one pretending to the name of philosopher, who could be so deaf as not to hear the voice of nature loudly proclaiming its Author from all, even the least of its parts. He gives us his sentiments on this, the most important of all subjects, in the appendix to his *Theoria*, in which he treats of God and of the soul of man.

38 The world cannot be the effect of chance. There, in the first place, he shows the absurdity of their opinion, who maintain that this world may have been the work of *chance*, the effect of a jumble of self-existent, self-moving atoms; because chance is an empty word without a real meaning. Whatever exists has its determinate cause, and can only be called *fortuitous* by us on account of our ignorance of that cause. Besides this, though the number of atoms composing this world is finite, yet their possible combinations are many times *infinitely infinite*: for they may be placed in infinite places of an infinite line; of these lines there is an infinite number in every *plane*, and of these planes there is an infinite number in space. Again, these points may have an infinite number of velocities in an infinite number of directions. From all this it is evident, that the combinations in which the points of matter may be, is infinite in a high degree, whereas *duration* can be infinite in only one dimension. Hence it is infinitely improbable that ever the present combination of things could come out by chance. And this is so much the more infinitely improbable, because the disorderly, chaotic combinations are infinitely more than the regular ones. The whole of matter might roll about in a blind motion for a boundless eternity, without ever being capable to produce one single mushroom.

Moreover, had matter been in motion from all eternity, every atom would have described an infinite line, and then a part of that line would be assignable at an infinite distance from the point of space in which the atom is at present: but an infinite line can never be run over; therefore the atom could never have come to its present

Bos-covich's System of Natural Philosophy. 39
 present place; and therefore the supposition is absurd. Nothing successive can be eternal with a *past* eternity, though it can continue without end. God alone can be eternal and actually infinite; but his eternity and infinity are beyond our comprehension.

Nor have existed from eternity.

Neither can the world have existed of itself in any thing like to its present form from all eternity; for matter is perfectly indifferent to numberless states, and to its present state it must be determined. This present state is perfectly incapable of determining itself, because this determination must be previous to its existence. It must be determined by the preceding state, which is also incapable of determining itself, and for its determination we must have recourse to the state before. Thus, though we go back to eternity, we shall still find a nullity of determination; now an infinite sum of *nothing* is *nothing*; and therefore as the present state of things could have no determination, it could not possibly exist.

It is therefore evident that there must be a Determiner extrinsic to the material word. This Determiner must have an infinite knowledge of all the possible combinations, and an infinite elective creative power to chuse and create freely the combination he pleased, in that point of eternity that he chose, with all the numberless circumstances that are agreeable to him.

40
 Attributes of God which appear in the creation.

And here what a vast field of contemplation is laid open to a philosophic mind! What a truly infinite knowledge was requisite to foresee so many ends, and so many means requisite for obtaining those ends, as are contained in the creation! Let us consider light, for example, which was to be emitted for so many ages from so many luminous bodies, with so great velocity, so as to penetrate so many mediums with different degrees of reflectibility and refrangibility, with so many other wonderful qualities; at the same time, so many bodies were to be perfectly fitted for reflecting this light in a certain manner, and the animal eye was to be so formed as to have a picture of visible objects painted on the bottom of it.—How many particular combinations were necessary for all this? What shall we say of the so many herbs, flowers, trees, and animal bodies, as there are on this our earth? All their kinds and species, all the series of their individuals, all their parts and particles, were foreseen, intended, and contrived, by one act of the Divine Mind. Again, how wonderful are the heavenly bodies, of what surprising magnitude, moving in the most beautiful order, at an immense distance from one another? To say nothing of the numberless creatures that are beyond the reach of the best telescope, or below that of the microscope. He who reflects ever so little on these things, must necessarily see the most evident proofs of an infinite power, wisdom, and providence; and he must be filled with admiration and awful respect for the Creator and Ruler of the universe.

41
 Natural religion.

Nor are we unconcerned spectators of this grand scene. God has been pleased to make us enter deeply into his great plan of creation. He singled us out among an infinite number of possible human beings, in order to call us into existence at a fixed period; and he has made a vast number of his creatures contribute to the formation of these wonderful machines, our bodies, as likewise to our nourishment, to our preservation, to our necessities, conveniences, and gratifications. Every

moment that we exist, we are enjoying a great number of benefits, expressly designed for us by that Supreme Being. This evidently demands from us the highest degree of gratitude, love, and obedience. Bosmen,

Let us go a step still farther: Is it not very reasonable to suppose, that our God, who affords us so many instances of his beneficence towards us in the natural order, will also, out of compassion to our weakness and ignorance, have favoured us with a more full and explicit manifestation of himself, of our duties towards him, and of his intentions concerning us? According to Bos-covich and all true philosophers, reason itself alone, and true philosophy, point out to us the probability at least of God's having given us a still better and surer guide, by whose direction we may attain to that perfect happiness which we naturally thirst after, and to which we must have been designed by our Maker. This is probable from reason alone; and of this great fact we are ascertained by unquestionable authority. 42
Revelation.

BOSHMEN have been generally described as a distinct race of Hottentots, who are enemies to the pastoral life (see *BOSHIES-MEN*, Encycl.) This M. Vaillant affirms to be a mistake; and we think he has completely proved that it is so. "These infamous wretches (says he) do not form a particular nation, nor are they a people who have had their origin in the places where they are now found. *Bosmen* is a name composed of two Dutch words, which signify *bush-men*, or *men of the woods*; and it is under this appellation that the inhabitants of the Cape, and all the Dutch in general, whether in Africa or America, distinguish those malefactors or assassins who desert from the colonies, in order to escape punishment. In a word, they are what in the British and French West India islands are called *Maroon Negroes*. These Bosmen, therefore, far from being a distinct species, are only a promiscuous assemblage of mulattoes, negroes, and mestizos, of every species, and sometimes of Hottentots and bastards (see *BASTER*, Supplement), who all differing in colour, resemble each other in nothing but in villany. They are land pirates, who live without laws and without discipline, abandoned to the utmost misery and despair; base deserters, who have no other resources but plundering and crimes. They retire to the steepest rocks and the most inaccessible caverns, and there they pass their lives. From these elevated places they command an extensive prospect over the surrounding plains, lie in wait for the unwary traveller and the scattered flocks, pour down upon them with the velocity of an arrow, and suddenly falling upon the inhabitants and their cattle, slaughter them without distinction. Loaded with booty, and whatever they can carry with them, they then repair to their gloomy caves, which they never quit till, like the lions, hunger again impels them to fresh massacres. But as treachery always marches with a trembling step, and as the presence of one resolute person is sufficient to overawe whole troops of these banditti, they carefully shun those plantations where they are certain that the owners themselves reside. Artifice and cunning, the usual resources of timid souls, are the only means which they employ, and the only guides that accompany them in their expeditions."—*Vaillant's Travels into the Interior Parts of Africa* (A).

BOSWELL

(A) Since this article was first published, a different account has been given of the *Bosmen* or *BOJESMANS* by Mr

Boswell.

BOSWELL (James), known to the learned world as the author of a life of Dr Johnson and of several other valuable works, was born, we believe, at Auchinleck in Airshire, in 1740. The family from which he sprung was ancient and honourable. At the time of his birth his father was a well employed lawyer at the Scotch bar; but was afterwards raised to the dignity of Judge, and filled that important station with acknowledged learning, probity, and honour. His title was Lord Auchinleck, taken from his family inheritance; and he died in 1782: on which occasion Dr Johnson wrote an elegant and instructive letter to the subject of this brief memorial; of which we shall transcribe a passage that alludes to some slight domestic differences, which did not happen in vain, since they gave rise to such salutary advice:

“Your father’s death had every circumstance that could enable you to bear it. It was at a mature age, and it was expected; and as his general life had been pious, his thoughts had, doubtless, for many years past, been turned upon eternity. That you did not find him sensible must doubtless grieve you; his disposition towards you was undoubtedly that of a kind, though not of a fond father. Kindness, at least actual, is in our own power, but fondness is not; and if, by negligence or imprudence, you had extinguished his fondness, he could not at will rekindle it. Nothing then remained between you but mutual forgiveness of each other’s faults, and mutual desire of each other’s happiness.”

The occasion of this family dissention is unknown to us. It might originate in the difference of their political principles, Mr Boswell being a zealous Tory, and his father, as he represents him, a rancorous Whig; or it may have arisen from the celebrated Douglas cause, which set many friends at variance in Scotland, and in which, though Lord Auchinleck and his son took the same side, they took it with very different degrees of ardour. The Judge saw not the propriety of illuminating his windows when the cause was finally decided by the House of Peers; and to compel him to illuminate, the advocate got possession of a Chinese gong, and at the head of a number of young men and boys patrolled the streets of Edinburgh, and made a loud and exulting noise at the windows of his father’s house, where there was no symptom displayed of the general joy.

In 1762 Mr Boswell made his first journey to London; where, under the auspices of Dodsley the bookseller, he published, “The Cub at Newmarket, a Tale.” By the title of *Cub* he meant to characterise himself, as the reader will perceive in the following lines, which we shall give as a specimen of the poem:

Lord Eglintoune, who loves, you know,
A little dash of whim, or so,
By chance a curious Cub had got,
On Scotia’s mountains newly caught.

During his stay in London Mr Boswell was introduced to Dr Johnson, with whom it is well known he

Boswell.

continued to live in intimacy from that time till Johnson’s death in 1784; and this intimacy procured him the friendship of Burke, Goldsmith, Sir Joshua Reynolds, and many other men of eminence, who composed what was called *The Literary Club*. In the latter end of 1765 he became acquainted with General Paoli when on his travels; and after his return he published, in 1768 or 1769, his account of Corsica, with the “Journal of a Tour to that Island.”

Of this work, which gained him some distinction in the world, his great friend Johnson writes thus: “Your history is like all other histories, but your journal is in a very high degree curious and delightful. There is between the history and the journal that difference which there will always be found between notions borrowed from without and notions generated within. Your history was copied from books; your journal rose out of your own experience and observation. You express images which operated strongly upon yourself, and you have impressed them with great force upon your readers. I know not whether I could name any narrative by which curiosity is better excited or better gratified.”

In 1770 Mr Boswell, who was then in good practice at the Scotch bar, married an amiable woman, by whom he had two sons and three daughters, who survived him. In 1773 he was chosen a member of the LITERARY CLUB; and in the autumn of the same year he visited the Hebrides in company with his illustrious friend Johnson; after whose death he published a very entertaining account of their tour; the places they saw, the characters with whom they conversed, and their own remarks on the different conversations. To many persons, both in England and Scotland, this book gave great offence, as it brought before the public the unguarded talk of private social circles; but it surely furnished much entertainment, as it exhibited a more faithful picture of Hebridian manners than the British public had ever before seen.

In 1784, when Mr Fox’s famous India bill was before Parliament, Mr Boswell published a “Letter to the People of Scotland on the Present State of the Nation;” in which he contends, that no charter would be safe if that bill should pass into a law; and more than insinuates, that the principle of it was equally inimical to the liberties of the subject and to the prerogative of the king. Dr Johnson seems to have thought of that bill as he did; for having read the letter, he writes to the author his approbation of it in the following words: “I am very much of your opinion; and, like you, feel great indignation at the indecency with which the king is every day treated. Your paper contains very considerable knowledge of the history and of the constitution, very properly produced and applied.”

In 1785, Mr Boswell quitted the Scotch bar, and went to reside in London, where he continued till the day of his death. Having entered himself in one of the inns of court, and studied the English law, he became a barrister in England: but we have reason to believe that

Mr Barrow, who travelled into the interior of Southern Africa in 1797 and 1798. According to him, they are a distinct race, extremely savage, who neither cultivate the ground nor breed cattle, but subsist in part on the natural produce of their country, and supply its deficiency by depredations on the colonists on one side, and the neighbouring tribes of people that are more civilized than themselves, on the other.

Boswell. that his practice there was not so successful as it had been in his own country. He enjoyed, however, more completely than he could do in Edinburgh, the conversation of the great, the wise, the witty, and the good; and such conversation he always valued above wealth. He frequently visited his native country, and especially Auchinleck, the seat of his ancestors; and soon after his return from one of those visits he was seized with a disorder which proved fatal, on Tuesday the 19th of May 1795.

Such were the principal events in the life of Mr Boswell. Of his character, it would be difficult to say *much more* than he has said himself in his "Journal of a Tour to the Hebrides;" and which may, with some propriety, be copied here:

"I have given a sketch of Dr Johnson. My readers may wish to know a little of his fellow-traveller. Think, then, of a gentleman of ancient blood; the pride of which was his predominant passion. He was then in his 33d year, and had been about four years happily married. His inclination was to be a soldier; but his father, a respectable Judge, had pressed him into the profession of the law. He had travelled a good deal, and seen many varieties of human life. He had thought more than any body supposed, and had a pretty good stock of general learning and knowledge. He had all Dr Johnson's principles, with some degree of relaxation. He had rather too little than too much prudence; and his imagination being lively, he often said things of which the effect was very different from the intention. He resembled sometimes

'The best good man, with the worst-natur'd muse.'

"He cannot deny himself the vanity of finishing with the encomium of Dr Johnson, whose friendly partiality to the companion of this tour, represents him as one whose acuteness would help my inquiry, and whose gaiety of conversation, and civility of manners, are sufficient to counteract the inconveniences of travel, in countries less hospitable than we have passed."

Few of Mr Boswell's friends, we believe, could add much to this candid confession. His enemies, if he had any, might dwell upon his failings; but his failings were few, and injurious to no person. In his character good nature was predominant. He appeared to entertain sentiments of benevolence to all mankind, and to be incapable of *intentionally* injuring a human being. His conversation-talents were always pleasing, and often fascinating. But can we wonder at this in him who, with a capacity to learn, had been the companion of Johnson for more than 20 years? His attachment to the Doctor for so long a period, was a meritorious perseverance in the desire of knowledge. To it the world is indebted for the most finished picture of an eminent man that ever was executed. We know there are objections to the *mode* of giving the life of Johnson. It has been thought that ignorance has been wantonly exposed, and the privacy of social life endangered. We shall not enter deeply into this question. All that we can certainly affirm is, that the work has been read with avidity and pleasure; and that he who does not wish to read it again may be suspected to be deficient in taste and in temper.

Mr Boswell has been accused of vanity; but when this accusation is brought against him, it should not be

forgotten that he enjoyed advantages which rendered that conspicuous in him from which no man can claim an exemption. We know not the man who would not have been vain to possess so much of Dr Johnson's conversation, and proud to give it to the world, in hopes that he who venerated Johnson would not be unthankful to his biographer. From the Doctor, however, he appeared to his friends to have imbibed a portion of melancholy, of which indeed he complained himself during the last two or three years of his life; and he flew for relief where perhaps it is best to be found, to the society of the learned and the gay. Here, as he confesses, he "had rather *too little* than too much *prudence*;" and, with more attachment to the activity of rural life, he might, probably, have lengthened his days. But as his "belief in revelation was unshaken," and his religious impressions deep, and recurring frequently, let us hope that he has now attained that state from which imperfection and calamity are alike excluded.

BOTANY-BAY. See *NEW HOLLAND*, Encycl.; and *New South WALES* in this Supplement.

BOUGUER (Peter), an eminent mathematician and mechanical philosopher, was born at Croisic, in Lower Bretagne, on the 10th of February 1698. His father John Bouguer, who was likewise a considerable mathematician, was then professor royal of hydrography at that port; and under him young Bouguer studied mathematics, and the application of them to ship-building, almost from the period when he began to speak; so that he was a proficient in these sciences before he had reached beyond the years of childhood. He was, however, removed from Croisic to the Jesuits college at Vannes, where, at 13 years of age, he triumphed, in a public contest, over a professor of mathematics, who had advanced a mathematical proposition erroneously. Two years after this he lost his father, whom he was appointed to succeed in the office of hydrographer, after being publicly examined, and giving the most complete proof of his being duly qualified to fill the vacant chair. He was indeed qualified by prudence as well as by science; for however surprising it may be, he filled it both with dignity and with abilities, though then not more than 15 years of age.

In the years 1727, 1729, and 1731, he gained the prizes successively proposed by the Academy of Sciences for essays on the best way of equipping ships with masts, on the best method of observing at sea the height of the stars, and on the most advantageous way of observing the declination of the magnetic needle or the variation of the compass. In 1729 he published an *Optical Essay upon the Gradation of Light*, in which he examined the intensity of light, and determined its degrees of diminution in passing through different pellucid mediums, and particularly in traversing the earth's atmosphere. Of this essay, which was written upon a subject that till then had not attracted the attention of philosophers, the reader will find some account in the *Encyclopædia Britannica*, under the title *OPTICS*, n^o 32, &c.

In 1730 Bouguer was removed from the port of Croisic to that of Havre. In 1731 he obtained, in the Academy of Sciences, the place of associate geometrician, vacant by the promotion of Maupertuis to that of pensioner; and in 1735 he was promoted to the office of pensioner-astronomer. The same year he was sent on the commission to South America, along with Messrs Godin,

Bouguer. Godin, Condamine, and Jeussieu, to determine the measure of the degrees of the meridian, and the figure of the earth. In this painful and troublesome business of ten years duration, chiefly among the lofty Cordelier mountains, our author, besides attending to the object of the voyage, made many scientific observations; viz. on the effect of the Cordeliers on the polarity of the magnetic needle; on the expansion and contraction of metals and other substances, by the sudden and alternate changes of heat and cold among those mountains; and on the refraction of the atmosphere from the tops of the same, with the singular phenomenon of the sudden increase of the refraction, when the star can be observed below the line of the level. He likewise ascertained the laws of the density of the air at different heights, from observations made at different points of those enormous mountains; he discovered that the mountains have an effect upon a plummet, though he did not assign the quantity of that effect; he found out a method of estimating the errors committed by navigators in determining their route; gave a new construction of the log for measuring a ship's way; and made several other useful improvements. M. Bouguer made at different times some important experiments on the famous reciprocation of the pendulum; he invented in 1747 the HELIOMETER (see that article *Encycl.*); and made many discoveries relating to the intensity of light (for which see *OPTICS-Index, Encycl.*) His unremitting application to study undermined his health, and he died on the 15th of August 1758, in the 61st year of his age.

Of his works which have been published, the chief are, 1. The Figure of the Earth, determined by the Observations made in South America, 1749, in 4to. 2. Treatise on Navigation and Pilotage, Paris, 1752, in 4to. This work has been abridged by M. La Caille, in one volume 8vo, 1768. 3. Treatise on Ships, their Construction and Motions, in 4to, 1756. 4. Optical Treatise on the Gradation of Light, first in 1729, then a new edition in 1760, in 4to.

His papers that were inserted in the Memoirs of the Academy are very numerous and important: as, in the Memoirs for 1726, comparison of the force of the solar and lunar light with that of candles; 1731, observations on the curvilinear motion of bodies in mediums; 1732, upon the new curves called the *lines of pursuit*; 1733, to determine the species of conoid, to be constructed upon a given base which is exposed to the shock of a fluid, so that the impulse may be the least possible; determination of the orbit of comets; 1734, comparison of the two laws which the earth and the other planets must observe in the figure which gravity causes them to take; on the curve lines proper to form the arches in domes; 1735, observations on the equinoxes; on the length of the pendulum; 1736, on the length of the pendulum in the torrid zone; on the manner of determining the figure of the earth by the measure of the degrees of latitude and longitude; 1739, on the astronomical refractions in the torrid zone; observations on the lunar eclipse of the 8th September 1737, made at Quito; 1744, short account of the voyage to Peru by the members of the Royal Academy of Sciences, to measure the degrees of the meridian near the equator, and from thence to determine the figure of the earth; 1745, experiments made at Quito and divers other places in the torrid zone, on the expansion and contraction of metals

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by heat and cold; on the problem of the masting of ships; 1746, treatise on ships, their structure and motions; on the impulse of fluids upon the fore parts of pyramids, having their base a trapezium; continuation of the short account given in 1744 of the voyage to Peru for measuring the earth; 1747, on a new construction of the log, and other instruments for measuring the run of a ship; 1748, of the diameters of the larger planets; the new instrument called a *heliometer*, proper for determining them, with observations of the sun; observation of the eclipse of the moon the 8th of August 1748; 1749, second memoir on astronomical refractions, observed in the torrid zone, with remarks on the manner of constructing the tables of them; figure of the earth determined by MM. Bouguer and Condamine, with an abridgment of the expedition to Peru; 1750, observation of the lunar eclipse of the 13th December 1750; 1751, on the form of bodies most proper to turn about themselves, when they are pushed by one of their extremities, or any other point; on the moon's parallax, with the estimation of the changes caused in the parallaxes by the figure of the earth; observation of the lunar eclipse the 2d of December 1751; 1752, on the operations made by seamen, called *corrections*; 1753, observation of the passage of Mercury over the sun the 6th of May 1753; on the dilatations of the air in the atmosphere; new treatise of navigation, containing the theory and practice of pilotage, or working of ships; 1754, operations, &c. for distinguishing, among the different determinations of the degree of the meridian near Paris, that which ought to be preferred; on the direction which the string of a plummet takes; solution of the chief problems in the working of ships; 1755, on the apparent magnitude of objects; second memoir on the chief problems in the working of ships; 1757, account of the treatise on the working of ships; on the means of measuring the light.

BREAD is so essential an article of food that every useful method of making it should be generally known. Much has accordingly been said on that subject (*Encycl.*) under the titles **BAKING, BARM, BREAD, and YEAST**; but, since the last of these articles was published, we have seen, in Dr Townson's *Travels in Hungary*, a method of making bread at Debretzen; of which, as it may sometimes be adopted with advantage in this country, an account may, with propriety, be inserted here.

In the baking of this bread, a substitute is used for yeast, which is thus made: Two good handfuls of hops are boiled in four quarts of water: this is poured upon as much wheaten bran as can be well moistened by it: to this are added four or five pounds of leaven; when this is only warm, the mass is well worked together to mix the different parts. This mass is then put in a warm place for 24 hours; and after that, it is divided into small pieces about the size of a hen's egg, or a small orange, which are dried by being placed upon a board, and exposed to a dry air, but not to the sun; when dry, they are laid by for use, and may be kept half a year. This is the ferment; and it may be used in the following manner: For a baking of six large loaves, six good handfuls of these balls, broken into fragments, are taken and dissolved in seven or eight quarts of warm water. This is poured through a sieve into one end of the bread trough, and three quarts more of warm water are poured through the sieve after it, and what

Bread. remains in the sieve is well pressed out. This liquor is mixed up with so much flour as to form a mass of the size of a large loaf: this is strewed over with flour; the sieve, with its contents, is put upon it, and then the whole is covered up warm, and left till it has risen enough, and its surface has begun to crack: this forms the leaven. Then 15 quarts of warm water, in which six handfuls of salt have been dissolved, are poured through the sieve upon it, and the necessary quantity of flour is added, and mixed and kneaded with the leaven: this is covered up warm, and left for about an hour. It is then formed into loaves, which are kept in a warm room half an hour; and after that, they are put in the oven, where they remain two or three hours, according to the size. The great advantage of this ferment is, that it may be made in great quantities at a time, and kept for use. Might it not on this account be useful on board of ships, and likewise for armies when in the field?

Bread, in whatever way it is made, is a dear article; and it may be a desirable object to many of our readers to know at what price the baker can afford to sell it. This depends upon the price of wheat, the quantity of flour which the wheat may give, the loss at the mill, the expence of grinding, and the expence of baking.

Of the price of wheat we can say nothing with precision, because it varies according to the goodness or badness of the crop, and other circumstances; but a bushel of Essex wheat, Winchester measure, may be taken, on an average, as weighing 60 lb. Sixty pounds of wheat will yield, exclusive of the loss in grinding and dressing, $45\frac{1}{2}$ lb. of that kind of flour which is called *seconds*; which alone is used, through the greatest part of England, for bread, and which makes, indeed, the best of all bread, though not the whitest. A peck of this flour, weighing 14 lb. will take up between six and seven pints of water, and give 18 lb. of excellent bread; or a bushel of flour, weighing 56 lb. will yield 72 lb. of bread. The expence of baking a bushel of such flour is, in Essex and some other English counties, about ninepence; viz. yeast, on an average, twopence; salt, before the late tax, one halfpenny; and baking, sixpence.

But *seconds* is not all that is got from wheat. A bushel of 60 lb. of wheat gives, besides $45\frac{1}{2}$ lb. of *seconds*, 13 lb. of offal, i. e. of *pollards* and *bran*; for the utmost loss in grinding and dressing a bushel of wheat should not exceed 1 pound 8 ounces. The millers, indeed, usually reckon on two pounds of loss; but we can say, with the utmost confidence, that the actual loss is rather less than we have stated it. A correspondent of ours, on whose accuracy we can depend, weighed, in 1795, two bushels, Winchester measure, the one of white and the other of red wheat, and found the weight of them both to be 122 lb. This wheat was ground by his own servants, and it yielded $121\frac{1}{2}$ lb. of meal, so that there was here but $\frac{1}{2}$ lb. lost of two bushels, or of 122 lb. in grinding. He admits that he suffered the stones to turn too close, and that the loss should therefore have been somewhat greater. The meal was dressed, as the wheat had been ground, under his own eye; and every possible precaution being taken to prevent his being deceived in the result, he had of flour, or *seconds*, $93\frac{1}{2}$ lb. and of bran and pollard $25\frac{1}{2}$ lb.; so that he lost, of two bushels, but $2\frac{1}{2}$ lb. both in grinding and

dressing. The offal, or bran and pollard, being dressed in a bolting mill, yielded as follows: Bread.

Sharps	6 lb. 0 oz.
Fine pollard	5 8
Coarse pollard	7 8
Broad bran	5 8

Altogether 24 8

There was lost, therefore, in bolting, only one pound; and of the sharps, about three pounds, if sifted, would have been good flour. Indeed were the sharps and fine pollard to be added to the flour, the bread would, perhaps, be better, and more wholesome, than without such addition. From these data, which we believe to be very accurate, it will be easy to calculate, if the price of wheat be given, what should be the price of flour per bushel and peck, the price of bread per pound, and the quantity of bread that should be sold for a shilling.

It is a fact, however, which should be attended to, that loaves are not always of the same weight, though made of equal quantities of the very same dough. This was fully ascertained some years ago at Paris. On a violent complaint that the bread was not always of the same standard weight, the bakers of the city were called before the police officers. They admitted the fact, that loaves, baked at the same time, and in the same oven, were seldom, if ever, of the same weight; but they insisted that they contained, each, the standard quantity of dough, and that the variety of weight among them must proceed from some cause, which they did not pretend to ascertain. The matter was referred to the Royal Academy of Sciences, which appointed one of its members to superintend, for some days, the whole process of baking. This being done, it was found that, of loaves baked in a large oven, those were always heaviest which occupied the centre of the oven, and that the bakers were innocent of the crime with which they were charged. The fact, we think, may easily be accounted for. Even in an oven there must be some condensation of steam; and, from the very shape of the oven, the greatest quantity must be condensed towards the centre. Hence the loaves in the centre are necessarily wetter and heavier than those round the circumference, if the plain of the oven has been equally heated.

BREAD of Rice might occasionally be of great use in many countries during a scarcity of wheat; but the method of making it is not generally known. It is indeed impossible to make bread of the flour of rice, which is harsh and dry like sand or ashes, by treating it in the manner in which wheat-flour is commonly treated; and therefore it has been proposed to mix it with an equal quantity of the flour of rye. But this method of using the flour of rice is a very uncertain remedy in case of want; since we can have no rice-bread if we have not rye. We are taught, however, in the *Journal des Sciences, des Lettres, et des Arts*, how to make excellent bread from rice alone, by a method which the author of the memoir says he learned from the natives of America.

According to this method of making the wished-for bread, the first thing to be done to the rice is, to reduce it to flour, by grinding it in a mill, or, if we have not a mill, it may be done in the following manner:

Bread,
Brewing

Let a certain quantity of water be heated in a saucepan or caldron; when the water is near boiling, let the rice we mean to reduce into flour be thrown into it: the vessel is then to be taken off the fire, and the rice left to soak till the next morning. It will then be found at the bottom of the water, which is to be poured off, and the rice put to drain upon a table placed in an inclined position. When it is dry, it must be beat to powder, and passed through the finest sieve that can be procured.

When we have brought the rice into flour, we must take as much of it as may be thought necessary, and put it into the kneading trough in which bread is generally made. At the same time we must heat some water in a saucepan or other vessel, and, having thrown into it some handfuls of rice, we must let them boil together for some time: the quantity of rice must be such as to render the water very thick and glutinous. When this glutinous matter is a little cooled, it must be poured upon the rice-flour, and the whole must be well kneaded together, adding thereto a little salt, and a proper quantity of leaven. We are then to cover the dough with warm cloths, and to let it stand that it may rise. During the fermentation, this paste (which, when kneaded, must have such a proportion of flour as to render it pretty firm) becomes so soft and liquid that it seems impossible it should be formed into bread. It is now to be treated as follows:

While the dough is rising, the oven must be heated; and, when it is of a proper degree of heat, we must take a stewpan of tin, or copper tinned, to which is fixed a handle of sufficient length to reach to the end of the oven. A little water must be put into this stewpan, which must then be filled with the fermented paste, and covered with cabbage or any other large leaves, or with a sheet of paper. When this is done, the stewpan is to be put into the oven, and pushed forward to the part where it is intended the bread shall be baked; it must then be quickly turned upside down. The heat of the oven acts upon the paste in such a way as to prevent its spreading, and keeps it in the form the stewpan has given it.

In this manner pure rice-bread may be made; it comes out of the oven of a fine yellow colour, like pastry which has yolk of eggs over it. It is as agreeable to the taste as to the sight; and may be made use of, like wheat-bread, to put into broth, &c. It must, however, be observed, that it loses its goodness very much as it becomes stale.

It may be here remarked, that the manner in which Indian corn is used in some countries, for making bread, can only produce (and does in fact produce) very bad dough, and of course very bad bread. To employ it advantageously, it should be treated like rice; and it may then be used, not only for making bread, but also for pastry.

BREWING is an art of vast importance, and has accordingly been explained in the Encyclopædia Britannica. A few improvements, however, have been made in the art, which, though not noticed in that Work, seem to be worthy of general attention, and, therefore, to deserve a place in this Supplement. The first, of which we shall give an account, is an invention of Mr WILLIAM KER of Kerfield, in the county of Tweeddale, for the saving of hops, and, at the same

time, giving to the liquor, whether ale, beer, or porter, a superior flavour and quality. Brewing.

The steam which arises from the boiling copper is known to be strongly impregnated with the essential oil of the hops, in which their flavour consists. Instead, therefore, of allowing it to escape and evaporate, as it does in the common mode of brewing, Mr Ker contrives to preserve and condense it, by means of a winding-pipe fixed to the copper, similar to the worm of a still, or by a straight pipe passing through cold water, or any other cooling medium. The oil and water, thus obtained, are returned into the worts when boiled, or the oil, after being separated from the water, along with which it had been exhaled, is returned into the worts after they are boiled; and the watery part, which, after the oil is separated, still continues impregnated with the aromatic taste and bitter of the hop, is returned into the next copper or boiling-vessel; and so on from one copper or boiling-vessel into another. By this process a considerable part of the hop and flavour, which is lost in the ordinary mode of brewing, is preserved: the flavour of the liquor is improved by the preservation of the finer parts of the aromatic oil: and the ale and beer are better secured from any tendency to acidity or putrefaction, and therefore must be fitter for home consumption and exportation. For this invention, which is certainly simple, and we think rational, Mr Ker obtained a patent, dated March 4. 1788.

On the 4th of June 1790, Mr JOHN LONG of Longville, in the county of Dublin, Ireland, obtained a patent for an improvement in brewing, resembling, in one particular, this invention of Mr Ker's. To his invention, however, he gives the name of *an entire new method*, in all the essential parts, of brewing good malt liquor; and therefore, as it comprehends the whole process of brewing, we shall lay it before our readers in the words of its author.

“ 1. For the better extracting from malt, place near a mash-tun a shallow copper or other vessel that will readily heat; the curb of which to be on a level with the tun, and to contain from two to six hogheads, according to the dimension of the tun, more or less; and, at the lower end of the copper, have a cock from two to five inches diameter, more or less, to conduct the heated liquor from the copper into a tube which passes down the external part of the tun, and enters it through an aperture about six inches from the bottom; then forming two revolutions, more or less, through the body of the tun, and communicating its heat to the wort as it passes through the tube; and then, at a convenient distance from the place it first entered, it runs from the tun into a cistern or tub, situate as near as convenient to the copper or heating-vessel. In the tub or cistern is to be placed a pump, for the purpose of conveying the cooler liquor back to the copper or heating-vessel again; there to receive the heat of 208 degrees, more or less (which it will require after the first half-hour), and then convey it through the mashing-tun as before, and in the same manner, as long as the working brewer or distiller may think necessary, to raise the mashing tun to any degree of heat required. By adhering to the foregoing process, the first liquor may, with the greatest safety, be let upon the malt from 20 to 30 degrees lower than the present practice; by which means it operates with gentleness, opens and ex-

Brewing. pands the malt and raw corn, and prepares it for the reception of sharper or warmer liquor, so as to extract the whole of the saccharine quality from the malt and raw corn. By the foregoing method, the mashing-tun, instead of losing its first heat (which it does by the present practice), continues to increase in heat every moment, by conveying the heated liquor through the tube into the tun; by which means, at the end of two hours, the working brewer or distiller can have the tun brought to any degree of heat he shall think best suited to the different qualities of the malt or raw corn. Persons who would wish to save expence, may heat their mashing-tun at the side or bottom by a large picce of metallic substance made fire proof, and fixed therein; which, in some degree, will answer the end proposed, but with great trouble and delay.

" 2. To prevent the wort from receiving a disagreeable flavour while in the under-back, a tube must be placed at the cock of the mashing-tun, to receive the wort as it comes off, and convey it to a great cistern or refrigeratory, which is supplied with a stream of water. The wort, passing through that medium in a spiral tube, soon loses that heat which so often proves prejudicial to the brewer and distiller in warm weather: then pass it from the tube into a vessel in which pumps are placed, to return the worts into the copper for the purpose of boiling off. All vessels for receiving the cold wort must be placed lower than the source whence the wort comes.

" 3. As the great object of long boiling the wort is remedied, by my invention of taking the extract from the hops in a separate manner from the worts, I boil my worts no longer than from 15 to 20 minutes; and, by pursuing that method, I save much time and fuel, and regulate my lengths accordingly.

" 4. I steep my hops, the preceding day to which they are to be used, in a copper or other vessel, with as much fluid, blood-warm, as will cover the hops, where it is to remain over a slow fire at least 14 hours, close covered; the copper at the tenth hour not to be of a greater heat than 175 degrees, continuing slow until the last hour. Then I bring the copper gradually to a simmer or slow boil; in which state I let it remain about 10 minutes, and then run off the fluid; and this I do at the same time the first wort is boiled off, that they may both pass together through the refrigeratory into the fermentation or working tun. After the foregoing operation, I cover the hops again with other liquor, and bring the copper to boil as soon as convenient, and let it remain in that state a considerable time, until the second worts are boiled off. Then I pass the hop-fluid with the wort, the same as in the first instance; and, if there is a third wort, I boil my hops a third time with small worts, and pass it off as before; by which means I gradually obtain the whole of the essential oil and pleasing bitter from the hops, which is effectually preserved in the beer.

" 5. To cool worts. When the wort is boiled off, it is conducted from the cock of the copper or boiler into a tube of a proper dimension, which passes the wort from the cock to the large cistern or refrigeratory, and there performs several revolutions, in a spiral manner, through the same tube; which is immersed in constant supply of cold water, where it loses the greatest part of its heat in a short time, and thence continues a

straight course through the tube, a little elevated and of a suitable length, placed in brick-work, until it meets a small refrigeratory, supplied with colder water from a reservoir made for that purpose at the head of the works; whence a continual stream runs on the surface of the tube down to the great refrigeratory, cooling the wort as it passes, in order to enable the working brewer or distiller to send it into the backs or working-tuns at whatever degree of heat he shall think proper. There is no other difference between brewer and distiller in this process, but that the distiller immediately passes the strong wort from the mashing-tun to the back, thro' the same machinery above inserted, and the tubes may be made of lead, or any other metallic substance.

" 6. To enable me to brew in the warm summer months, I sink my backs or working-tuns at least to a level with the ground, but if deeper the better, and cover them closely by an arch made of bricks, or other materials, that will totally exclude the atmospheric air from them. I place them as near as possible to a spring or sand-drain, as their depth will naturally draw the water thence, which must be so contrived as to pass or flow round the backs or tuns. I then introduce a large tube, which passes through the tuns, and keeps the wort several degrees lower than can possibly be done by the present practice; by which means I can produce a complete fermentation even in the dog-days.

" 7. In cold or frosty weather, if the tun and backs should lose the first heat, intended to carry it through the process by the foregoing method, you may convey a supply of warm or boiling water by the tube, which passes through the body of the backs or tun, communicating its heat, which rises to any degree the working brewer shall think proper: by pursuing this method, in the coldest season, I never want a fermentation."

We regret that we cannot with propriety state to our readers, under this article, a summary of Mr Richardson of Hull's *Philosophical Principles of Brewing*; for as the author has a new edition of his work in the press, it is our duty rather to refer to it, than to quote from a former edition, which contains not his last improvements. See FERMENTATION and MALT, in this Supplement.

BRIDEALE. See SCOTALE in this Supplement.

BRIDGE. See that article (*Encycl.*), and ARCH in this Supplement. A wooden-bridge, of large span, should be constructed on the principles explained under the title ROOF (*Encycl.*) See also CENTRE (*Suppl.*)

BRINDLEY (James), was born at Tunsted, in the parish of Wormhill, Derbyshire, in 1716. His father was a small freeholder, who dissipated his property in company and field amusements, and neglected his family. In consequence, young Brindley was left destitute of even the common rudiments of education, and till the age of 17 was casually employed in rustic labours. At that period he bound himself apprentice to one Bennet, a mill-wright at Macclesfield, in Cheshire, where his mechanical genius presently developed itself. The master being frequently absent, the apprentice was often left for weeks together to finish pieces of works concerning which he had received no instruction; and Bennet, on his return, was often greatly astonished to see improvements in various parts of mechanism, of which he had no previous conception. It was not long before the millers discovered Brindley's merits, and preferred

Brindley. ferred him in the execution of their orders to the master or any other workman. At the expiration of his servitude, Bennet being grown into years, he took the management of the business upon himself, and by his skill and industry contributed to support his old master and his family in a comfortable manner.

In process of time Brindley set up as a mill-wright on his own account; and by a number of new and ingenious contrivances greatly improved that branch of mechanics, and acquired a high reputation in the neighbourhood. His fame extending to a wider circle, he was employed, in 1752, to erect a water-engine at Clifton, in Lancashire, for the purpose of draining some coal mines. Here he gave an essay of his abilities in a kind of work for which he was afterwards so much distinguished, driving a tunnel under ground through a rock nearly 600 yards in length, by which water was brought out of the Irwell for the purpose of turning a wheel fixed 30 feet below the surface of the earth. In 1755 he was employed to execute the larger wheels for a silk mill at Congleton: and another person, who was engaged to make other parts of the machinery, and to superintend the whole, proving incapable of completing the work, the business was entirely committed to Brindley; who not only executed the original plan in a masterly manner, but made the addition of many curious and valuable improvements, as well in the construction of the engine itself, as in the method of making the wheels and pinions belonging to it. About this time, too, the mills for grinding flints in the Staffordshire potteries received various useful improvements from his ingenuity.

In the year 1756 he undertook to erect a steam engine, upon a new plan, at Newcastle-under-Line; and he was, for a time, very intent upon a variety of contrivances for improving this useful piece of mechanism. But from these designs he was, happily for the public, called away to take the lead in what the event has proved to be a national concern of capital importance—the projecting the system of canal navigation. The Duke of Bridgewater, who had formed his design of carrying a canal from his coal-works at Worsley to Manchester, was induced by the reputation of Mr Brindley to consult him on the execution of it; and having the sagacity to perceive, and strength of mind to confide in, the original and commanding abilities of this self-taught genius, he committed to him the management of the arduous undertaking. The nature of this enterprise has already been described (*Encycl.* vol. IV. p. 8c.); it is enough here to mention, that Mr Brindley, from the very first, adopted those leading principles, in the projecting of these works, which he ever after adhered to, and in which he has been imitated by all succeeding artists. To preserve as much as possible the level of his canals, and to avoid the mixture and interference of all natural streams, were objects at which he constantly aimed. To accomplish these, no labour or expence was spared; and his genius seemed to delight in overcoming all obstacles by the discovery of new and extraordinary contrivances.

The most experienced engineers upon former systems were amazed and confounded at his projects of aqueduct bridges over navigable rivers, mounds across deep valleys, and subterraneous tunnels; nor could they believe in the practicability of some of these schemes till

they saw them effected. In the execution, the ideas he followed were all his own; and the minutest, as well as the greatest, of the expedients he employed, bore the stamp of originality. Every man of genius is an enthusiast. Mr Brindley was an enthusiast in favour of the superiority of canal navigations above those of rivers; and this triumph of art over nature led him to view with a sort of contempt the winding stream, in which the lover of rural beauty so much delights. This sentiment he is said to have expressed in a striking manner at an examination before a committee of the House of Commons, when, on being asked, after having made some contemptuous remarks relative to rivers, what he conceived they were created for? he answered, “to feed navigable canals.” A direct rivalry with the navigation of the Irwell and Mersey was the bold enterprise of his first great canal; and since the success of that design, it has become common, all over the kingdom, to see canals accompanying, with insulting parallel, the course of navigable rivers.

After the successful execution of the Duke of Bridgewater's canal to the Mersey, Mr Brindley was employed in the revived design of carrying a canal from that river to the Trent, through the counties of Chester and Stafford. This undertaking commenced in the year 1766; and from the great ideas it opened to the mind of its conductor, of a scheme of inland navigation which should connect all the internal parts of England with each other, and with the principal sea-ports, by means of branches from this main stem, he gave it the emphatical name of the *grand trunk*. In executing this, he was called upon to employ all the resources of his invention, on account of the inequality and various nature of the ground to be cut through: in particular, the hill of Harecastle, which was only to be passed by a tunnel of great length, bored through strata of different consistency, and some of them mere quicksand, proved to be a most difficult, as well as expensive, obstacle, which, however, he completely surmounted. While this was carrying on, a branch from the grand trunk, to join the Severn near Bewdly, was committed to his management, and was finished in 1772. He also executed a canal from Droitwich to the Severn; and he planned the Coventry canal, and for some time superintended its execution; but on account of some difference in opinion, he resigned that office. The Chesterfield canal was the last undertaking of the kind which he conducted, but he only lived to finish some miles of it. There was, however, scarcely any design of canal-navigation set on foot in the kingdom, during the latter years of his life, in which he was not consulted, and the plan of which he did not either entirely form, or revise and improve. All these it is needless to enumerate; but, as an instance of the vastness of his ideas, it may be mentioned, that on planning a canal from Liverpool to join that of the Duke of Bridgewater at Runcorn, it was part of his intention to carry it, by an aqueduct bridge, across the Mersey, at Runcorn Gap, a place where a tide, sometimes rising fourteen feet, rushes with great rapidity through a sudden contraction of the channel. As a mechanic and engineer, he was likewise consulted on other occasions; as with respect to the draining of the low lands in different parts of Lincolnshire and the Isle of Ely, and to the cleansing of the docks of Liverpool from mud. He pointed out a

Brindley. method, which has been successfully practised, of building sea-walls without mortar; and he was the author of a very ingenious improvement of the machine for drawing water out of mines by the contrivance of a lifting and a gaining bucket.

The intensity of application which all his various and complicated employments required, probably shortened his days; as the number of his undertakings, in some degree, impaired his usefulness. He fell into a kind of chronic fever, which, after continuing some years, with little intermission, at length wore out his frame, and put a period to his life on September 27, 1772, in the 56th year of his age. He died at Tunhurst, in Staffordshire, and was buried at New Chapel in the same county.

In appearance and manners, as well as in acquirement, Mr Brindley was a mere peasant. Unlettered, and rude of speech, it was easier for him to devise means for executing a design than to communicate his ideas concerning it to others. Formed by nature for the profession he assumed, it was there alone that he was in his proper element; and so occupied was his mind with his business, that he was incapable of relaxing in any of the common amusements of life. As he had not the ideas of other men to assist him, whenever a point of difficulty in contrivance occurred, it was his custom to retire to his bed, where, in perfect solitude, he would lie for one, two, or three days, pondering the matter in his mind till the requisite expedient had presented itself. This is that true inspiration which poets have almost exclusively arrogated to themselves, but which men of original genius in every walk are actuated by, when, from the operation of the mind acting upon itself, without the intrusion of foreign notions, they create and invent.

A remarkably retentive memory was one of the essential qualities which Mr Brindley brought to his mental operations. This enabled him to execute all the parts of the most complex machine in due order, without any help of models or drawings, provided he had once accurately settled the whole plan in his mind. In his calculations of the powers of machines, he followed a plan peculiar to himself; but, indeed, the only one he could follow without instruction in the rules of art. He would work the question some time in his head, and then set down the result in figures. Then taking it up in this stage, he would again proceed by a mental operation to another result; and thus he would go on by stages till the whole was finished, only making use of figures to mark the several results of his operations. But though, by the wonderful powers of native genius, he was thus enabled to get over his want of artificial method to a certain degree; yet there is no doubt that when his concerns became extremely complicated, with accounts of various kinds to keep, and calculations of all sorts to form, he could not avoid that perplexity and embarrassment which a readiness in the processes carried on by pen and paper can alone obviate. His estimates of expence have generally proved wide of reality; and he seems to have been better qualified to be the contriver, than the manager of a great design. His moral qualities were, however, highly respectable. He was far above envy and jealousy, and freely communicated his improvements to persons capable of receiving and executing them; taking a liberal satisfaction in forming a new generation of engineers able to proceed

with the great plans in the success of which he was so deeply interested. His integrity and regard to the advantage of his employers were unimpeachable. In fine, the name of Brindley will ever keep a place among that final number of mankind who form eras in the art or science to which they devote themselves, by a large and durable extension of its limits.

BRISSOT (J. P.), acted so conspicuous a part in the French revolution, that a fair detail of the principal events of his life would undoubtedly be acceptable to all our readers. A fair detail, however, of such a life, we believe it impossible at present to give; for characters like Brissot's are almost always misrepresented both by their friends and by their enemies; and till the troubles which they have excited, or in which they have been engaged, have long subsided, the impartial truth is nowhere to be found.

In a fulsome panegyric, under the denomination of *The Life of J. P. Brissot*, said to be written by himself, we are told, that he was born January 14, 1754; and that his father was a *traiteur*, or "the keeper of an eating-house," but in what place we are not informed. Our author, however, assures us that the old man was in easy circumstances, and that he employed all the means resulting from them to give to his numerous family a good education. The subject of this memoir was intended for the bar; but not relishing the studies necessary to fit him for the profession of the law, or, if we choose to believe him, having a mind too *pure* and *upright* for the study of *chicane*, he relinquished the pursuit after five years of drudgery!

To relieve his weariness and disgust, he applied himself, he says, to literature and the sciences. The study of the languages was above all others his favourite pursuit. Chance brought him acquainted with two Englishmen on their travels through France: he learned their language; and this circumstance, he tells us, decided his fate.

"It was at the commencement of my passion for that language (continues he) that I made the metamorphosis of a diphthong in my name which has since been imputed to me as so heinous a crime. Born the thirteenth child of my family, and the second of my brothers in it, I bore, for the sake of distinction, according to the custom of Beauce, the name of a village in which my father possessed some landed property. This village was called *Ouarville*, and *Ouarville* became the name by which I was known in my own country. A fancy struck me that I would cast an English air upon my name; and accordingly I substituted, in the place of the French diphthong *ou*, the *w* of the English, which has precisely the same sound." For this puerile affectation, which was certainly not criminal, he justifies himself by the example of the literati of the 16th and 17th centuries, who made no scruple of Grecizing and Latinizing their appellatives.

Having prosecuted his studies for two years, he had an application from the English proprietor of a paper then much in circulation, and intitled *Le Courier de l'Europe*. This man having drawn upon himself an attack from government, felt and yielded to the necessity of printing his paper at Boulogne-sur-mer. It was his wish to render it interesting to the French in the department of miscellaneous intelligence; which he therefore wished to submit to the superintendency and arrangement

Brissot.

of Brissot, who represents himself as for some moments hesitating. The profession of a journalist, subject to a licensor, was repugnant to his principles; yet it secured his independence, and put into his power the means of prosecuting an investigation of constitutions and of the sciences. After some ridiculous reasoning from the original stations of *Bayle*, *Postel*, and *Rousseau*, he at last accepted of the employment, and became enamoured of it, "because (says he) it enabled me to serve talents and virtue, and, as it were, to inoculate the French with the principles of the English constitution."

This employment, however, did not last for any length of time. The plan of the proprietor of the *Courrier* was overthrown by administration, and Brissot quitted Boulogne to return to his first studies. Having informed us of this fact, he makes an extravagant pretence to unfulfilled virtue, and calls upon the inhabitants of the city which he had left to bear witness, not only that he had *no vices*, but that he had not even the *seeds* of any one of the vices which his adversaries, it seems, had laid to his charge.

"Doubtless (says he), too eager to publish my ideas, I conceived that the proper moment had arrived, and I felt an inclination to commence with an important work. Revolting, from the very instant of my beginning to reflect, against religious and political tyranny, I solemnly protested, that thenceforward I would consecrate my whole life to their extirpation. Religious tyranny had fallen under the redoubled strokes of *Rousseau*, of *Voltaire*, of *Diderot*, and of *D'Alembert*. It became necessary to attack the second;" and this was a task which the vanity of Brissot led him to consider as reserved for him.

What *Voltaire* and his friends meant by religious tyranny, and how they conducted their attacks against it, are matters, alas! too well known to all Europe; and as our author chose these philosophers for his guides, we might infer, without much degree of mistake, what he understood by political tyranny, and by what means he meditated its extirpation. But he has not left us to make this discovery by inference.

"It became necessary (says he) to break in pieces the political idol, which, under the name of *monarchy*, practised the most violent despotism; but to attack it openly, was to expose the assailant without the possibility of serving mankind. It was by a side blow that it was to be wounded most effectually;" and therefore he resolved to begin his operations by attacking some of those abuses which might be reformed without apparently shaking the authority of the prince.

Our readers, at least the sober part of them, will probably think that this mode of attack is not peculiar to Brissot, but that it has been practised, or attempted to be put in practice, by aspiring demagogues in all ages and countries, who have uniformly begun their career of innovation by exciting the public mind against those abuses in government, of which the existence cannot wholly be denied. The subject to which our author thought fit to call the attention of his countrymen, was the criminal jurisprudence: a subject, says he, which, with the exception of some particulars that had been successfully investigated by *Beccaria* and *Servan*, no writer had thoroughly considered in a philosophical point of view. Thinking himself fully equal to this task, he drew up a general plan; and in the year 1780 publish-

Brissot.

ed his *Theory of Criminal Laws*, in two vols 8vo. This work, favourably received by foreigners, applauded by some journalists, and pulled to pieces by others, procured him the friendship of the warmest advocates for human liberty, in whose opinion the defects of his plan were highly pardonable, on account of the energy conspicuous in his remarks. This publication was soon followed by two discourses which gained the prize in 1782 at the academy of *Chalons-sur-Marne*; the one upon the reform of the criminal laws, and the other on the reparation due to innocent persons unjustly accused.

It is natural to suppose that the government beheld with an evil eye these writings, which, under pretext of dragging into light the abuses of the criminal laws, insinuated dangerous principles on the nature of government in general.

His next work was intitled, *A Philosophical Library of the Criminal Laws*, in 10 vols; the true object of which was to disseminate in France those principles of liberty which guided the English and the Americans in framing and expounding their laws.

But the study of legislation and politics had not entirely drawn him off from that of other sciences; such as chemistry, physics, anatomy, theology, &c. These he constantly cultivated with ardour; but acknowledges that in each he met with obscurities, and that in every quarter truth escaped from his researches. He therefore sat down to investigate the nature of truth, and the proper method of attaining to it in every department of research; and the result of his labours was a kind of *novum organum*, by which he seems to have expected that *Bacon's* work would be buried in oblivion; and to this important volume he gave the title of *Concerning Truth*; or, *Thoughts on the Means of attaining Truth in all the Branches of Human Knowledge*. This volume was meant as nothing more than the introduction to a greater work, in which he proposed to investigate what is *certain* in knowledge and what *doubtful*, and then to strike the balance of the account.

He was prevented, however, from completing his plan, which he regrets exceedingly; for, as he affirms, with *becoming modesty*, his work would certainly have amended its readers! But the French government happened to think otherwise; his aim, which, he says, was to lead mankind to reflect on their rights, was perceived, and he was accused to the minister as a seditious writer. The career of genius was stopped by the dread of the *Bastille*; and he was obliged to take refuge in London. There it was his wish to create a *universal confederation of the friends of liberty and truth*, and to establish a *centre of correspondence and union* with the learned and the politicians of Europe. This dark design, however, was frustrated by the treachery, as it would appear, of his associates, who had bound themselves, he says, by the most *sacred oaths*, to assist him, and had offered to sign articles *even with their own blood*.

Finding himself unable to proceed directly to the object which he had in view, he resolved to *enlighten his countrymen* gradually, and to begin with exciting their love and admiration of the English constitution. That constitution, which he had investigated on the spot, appeared to him a model for those societies which were desirous of changing their form of government. It was but little known, he says, in France (the work of *De Lolme* being at that time only in the hands of the learn-

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ed); and to make it known was to make it beloved, was to render it desired. But the French ministers stood upon their guard, and it became necessary to *deceive* them. He resolved therefore to bring forward a journal written actually in London, and professing to contain only a *description of the sciences and arts of England*, whilst the greater part of it was to be occupied in reality by an investigation of the *English constitution*.

After many difficulties, the ministry granted a privilege for this journal, being published in London, to be reprinted in Paris; and it first appeared in 1784. "In the twelve numbers which have been published (says the author), the friends of liberty must have perceived, that if, on the one side, I endeavoured to inculcate more just ideas than had hitherto been entertained concerning this celebrated island; so, on the other, I resolutely made my advances toward that important end which has perpetually presided over all my labours, *the universal emancipation of men.*"

His affairs calling him at this time to Paris, he was arrested and conveyed to the Bastille on the 12th of July 1784. In this conduct of the government we cannot perceive any thing very tyrannical or arbitrary, since he confesses, that, in the 16th page of the first number of his Journal, he had suffered the *secret and favourite aim*, which always guided his pen, to become discernible. He was, however, discharged from prison on the 5th of September, and returned with increased zeal to his former employments.

"This persecution (says he), far from extinguishing the ardour of my wishes to inculcate the principles of freedom, served only to inflame it the more." Accordingly, in 1785, he published two letters to the Emperor Joseph II. *concerning the right of emigration, and the right of people to revolt*. The first of these letters, which, though well known in Germany, were in France suppressed by the *police*, was occasioned by what the author calls the ridiculous and barbarous edict against emigration; and the second by the punishment of *Horriah* the chief of the *Walachian* insurgents. In this last letter he lays it down as a maxim, that all people under such a government as that of the *Walachians*, have from nature a sacred *right* to revolt, a right which they can and ought to exercise. In the same spirit he brought out, in 1786, his Philosophical Letters on the History of England, in 2 vols, and A Critical Examination of the Travels of the Marquis de Chatelleux in North America.

The French revolution appearing to him extremely distant, notwithstanding all his efforts to hasten it, he resolved to leave France for the purpose of settling in America. His project received the approbation of several, whose sentiments were congenial with his own. But as it was thought imprudent to transport numerous families to a country so far off, without thoroughly knowing it, Brissot was engaged to proceed thither, to examine the different places, to observe the inhabitants, and to discover where and in what manner the establishment they had proposed might be most advantageously fixed. He had some time before instituted a society at Paris for accomplishing the abolition of the negro trade, and for softening the condition of the slaves. At the period of his departure, this society consisted of a considerable number of distinguished members, and he was commissioned to carry the first fruits of their labours to

America. His stay there, however, was not so long as he was desirous of making it. In the beginning of 1789 he was recalled by the news of the French revolution, which he conceived might probably produce a change in his own measures and in those of his friends. This idea, added to other circumstances, accelerated his return. The fire had blazed forth in his native country. "Hope (says he) animated every heart; the most distinguished champions had engaged in the contest; I too became desirous to break a lance, and I published my *Plan of Conduct for the Deputies of the People.*"

This, and other works of a similar kind, of which he loudly boasts the merits, raised him high in the favour of the republican part of the nation, and he became president of his district; where he acted, according to his own account, with great uprightness in the municipality, in the first committee of inquiries, and as an elector. At last he became a member, first of the *National Assembly*, and, after its dissolution, of the *Sanguinary Convention*; and by some means or other got to be the leader of a party called sometimes the *Girondists*, and sometimes the *Brissotines*. From that period the principal events of his life were involved with the public transactions of the nation, of which we have given an account in the *Encyclopædia* under the title *REVOLUTION* (see that article, n° 101—182.) The Girondist faction was denounced by the Mountain, and Brissot suffered by the guillotine on the 30th of November 1793. He fell indeed by a very unjust sentence; but his fall was the natural consequence of that anarchical tyranny under which no man had contributed more than he to subject his native country.

BROWN (Dr John), author of the *Elementa Medicinæ*, &c. was born in the village of Dunse, or, as some say, Lintlaws, in the county of Berwick, in the year 1735-6. His parents were of mean condition, but much respected in the neighbourhood for the integrity of their lives. His father gained his livelihood in the humble capacity of a day-labourer; while his mother contributed her share towards the support of the family by the profits arising from a milch cow.

Such were the persons who, in an obscure part of the country, gave birth to a son destined, at a future period, to make a distinguished figure in the republic of letters; and from whom originated a system of the animal economy, which, whatever be its real merits, has undoubtedly produced a considerable revolution in the practice of medicine.

At the age of three or four years, young Brown was put to a reading school in Dunse, which he himself commemorates as the place rather of his education than of his nativity. Here, under the tuition of an old woman, he very early began to exhibit marks of that strength of mind for which he was afterwards so eminently distinguished. In the short period of a year he became able to read with facility any part of the Bible, and acquired over his class-fellows that superiority which he ever after maintained both at school and college.

It was almost immediately after his entrance into this school, that his insatiable desire of reading commenced; and so unremitting was his application, that he is said never to have been found, even at those hours which children much more advanced in life devote to amusement, without a book in his hand.

While he was making this rapid progress in the rudiments

diments of literature, he suffered what must have appeared to be a very heavy loss in the death of his father; but his mother soon afterwards married a worthy man of the same name, whose care and attention supplied the place of a father to her son. This man being a weaver, designed to educate his son-in-law to the same business, and began to instruct him in his art when he was about nine years of age; but the taste which young Brown had already acquired for letters, made him look with disgust on the insipid employment of a weaver. His step-father was no tyrant, and his mother was affectionate. They were both proud of the talents which at so early a period of life had appeared in their son, and they felt no inclination to struggle with the invincible aversion which he expressed to the business for which they intended him.

Another circumstance, however, contributed in no small degree to make them recal their original resolution. They were both of that sect of religionists which in Scotland are called Seceders (see *SECEDERS, Encycl.*); and it was suggested to them by some persons of their own persuasion, who had remarked the uncommon abilities of the boy, that he might one day prove an able support and promoter of their tenets as a preacher. He was accordingly, much to his satisfaction, taken away from the business to which he had conceived such a distaste, and sent to the grammar-school of Dunse, which was taught at that time by a gentleman of the name of Cruickshank, eminent for his grammatical knowledge. Here he appears to have spent some years with uncommon advantage and happiness; during which he was esteemed by all the country round as a kind of prodigy. Like Johnson, and many other men of the highest celebrity, he united in the same person uncommon powers of mind, with no less strength of body, as indeed his appearance indicated; and in his youth he ensured his own personal importance among his school-fellows, by excelling them not less in athletic exercises than in the tasks prescribed by their master. He was particularly fond, when a boy, of practising the pugilistic art; and indeed until the last period of his life he was observed by his friends always to view an exhibition of that kind with peculiar relish. He also prided himself much in being a stout walker; and mentions his having in one day accomplished, when but fifteen years of age, a journey of fifty miles between Berwick-upon-Tweed and Morpeth in Northumberland. When farther advanced in life, he travelled on foot from four in the afternoon of one day to two in the afternoon of next day, with the short interval of one hour's rest! But as one of his biographers very justly observes, "we have seen that he could make a more rational use of his strength than merely to stake it against time and space *."

His early years while at school were marked by the most rigid attachment to his sect. So strict indeed were his religious sentiments, if a boy of ten or eleven can be said to have any sentiments deserving to be called religious, that he would have conceived the holding of any communion with the established church as a kind of profanation. An event, however, happened, some time between the eleventh and thirteenth years of his age, which produced a total and unexpected revolution in his religious opinions. At a meeting of the provincial synod of Merse and Tiviotdale, he was prevailed upon,

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though not without manifesting much reluctance, to accompany a party of his school-fellows to the parish church of Dunse. The consequence of this transgression, as he had dreaded, was an immediate summons to appear before the session of the Seceding congregation; to which, through pride, not choosing to attend, in order to preclude a formal expulsion, he voluntarily abjured their tenets, and openly avowed his apostacy to the establishment.

All changes in religion which are not the consequence of candid investigation are dangerous. He who leaves one sect he knows not why, will quickly abandon, with as little reason, that to which in a fit of passion he had hastily joined himself. From the moment of his quitting the communion of the Seceders, Brown's religious ardour suffered a gradual abatement; and though, to please his mother, he continued to prosecute his studies with a view to the office of a clergyman in the church of Scotland, his opinions became daily more and more lax, and his life of course less and less regular. It was, however, a considerable time before he admitted, in their full extent, those principles of irreligion which he afterwards avowed; for upon his first perusing the *Essays* of Mr Hume, though his own zeal was then much cooled, he expressed great indignation at their dangerous tendency.

At the age of twelve years he had been employed by Mr Cruickshank as a kind of usher in the school of Dunse; and that gentleman having declared that his knowledge of the Latin language was equal to his own, his fame as a scholar was so spread over the country, that at the age of thirteen he was intrusted with the education of a gentleman's son in the neighbourhood, when he quitted the school and his beloved master. In his new situation, however, he remained not long. Dr Beddoes conjectures, that to the stiffness of pedantry he added the sourness of a bigot, and was therefore a disagreeable inmate of the family. That a boy of thirteen, proud of his talents, and prouder of his learning, should have the stiffness of a pedant, is indeed extremely probable; it was the natural consequence of the praise with which he had been honoured by Mr Cruickshank: but there is reason to believe that of his original bigotry few traces now remained. The real cause of his dismissal from the family, we are assured, was his pride; and as it must have been the pride of parts, it confirms the first part of Dr Beddoes's conjecture.

It seems he was much displeased that, when company were at dinner, he was not desired to remain after the cloth was removed; and yet if he was then only thirteen years of age, it is not easy to conceive for what purpose he should have staid. He could not possibly know much of the world, or of any thing likely to employ the conversation of country gentlemen; and we cannot help thinking, that the master of the house would have treated his guests with rudeness, had he detained among them a raw boy to listen to every unguarded expression which might escape them over their wine. It would appear, however, that he was not unwilling to give the tutor of his son an opportunity of displaying his abilities, when such subjects were introduced as he knew him to have studied; for a dispute having arisen, one day after Brown had retired to his own room, concerning the decrees of Providence, he sent to request his opinions on that abstruse subject. By

Brown. the messenger Brown returned a verbal answer, that "the decrees of Providence are very unjust, for having made blockheads lairds."

Mr Cruickshank had some time before requested him to return to the situation which he had formerly held in the school of Dunfe; and we cannot wonder that, immediately after making this insolent answer, he found it convenient to comply with his request. He was now about fifteen, and he continued in the school till the 20th year of his age; during which time, from the constant habit of teaching the Latin and Greek languages, he acquired a wonderful facility in reading both these languages, and in writing the former, though he wrote not with taste.

About this time it occurred to him that he might turn his classical acquirements to more account, by becoming a private teacher of languages in Edinburgh. To that city he accordingly repaired, where, while he obtained a livelihood as a teacher, he proposed at the same time to pursue his theological studies at the university. But an accident happened to him here which made him altogether change the plan he had come upon; and the death of his mother, after a residence of some time in Edinburgh, absolved him, as he thought, from the promise which he had made to her of appearing one day in the pulpit. Shortly after an unsuccessful competition for one of the chairs then vacant in the high-school, an application was made to a friend of his for a proper person to turn a medical thesis into Latin. Brown was recommended. He was limited to a certain time; within which it appeared scarce practicable to perform the task. He accomplished it, however, and in such a style of grammatical correctness and purity as far exceeded the general run of such productions. On this being remarked to him by his friends, he observed, "that he now knew his strength, and was ambitious of riding in his carriage as a physician." He therefore determined to apply himself with ardour to the study of medicine, to which this accidental circumstance alone directed his attention. Accordingly, at the commencement of the next winter session, he addressed a Latin letter to each of the medical professors, and by them was presented with tickets of admittance to their several classes.

From such a favourable beginning, being of a very sanguine disposition, he conceived the most flattering expectations of his future success; and indeed for some time he seems to have lived in affluent circumstances. His attainments were so various, and in such request in Edinburgh, that as a single man he could scarcely fail to gain a competent living; for during the last five years of his residence under Mr Cruickshank, to a thorough acquaintance with ancient history, he had added a very considerable knowledge of mathematics; in which, among other branches of science, he never had any objection to give instructions. In the acquisition of that variety of knowledge which he possessed, he was greatly assisted by a most tenacious memory; to the retentiveness of which an old school-fellow bears testimony, by affirming, that "after once reading over the lesson, consisting of two octavo pages in Latin, he would lay aside the book, and prelect the whole over without mistaking a single word."

Brown, already in easy circumstances for an individual, saw, or thought he saw, in the establishment of a boarding-house for students a resource which would en-

able him to maintain a family; and in expectation of realising this prospect, he married, in 1765, the daughter of a respectable tradesman in Edinburgh. The distinguished attention at that time paid him by Dr Cullen, in whose family he had become a necessary person, contributed in all probability to strengthen his hopes that his house would be filled with proper boarders through the Doctor's recommendation. His success in this way for some time answered his most sanguine expectations; and his circumstances at one period were so flourishing, that he is said to have kept a one-horse chaise.

It was, perhaps, the greatest misfortune that could have befallen Brown, that he possessed, in a high degree, those talents which make a man's company sought after by the gay and the dissipated: He was capable of "setting the table in a roar." We need not therefore wonder at his frequently neglecting more necessary pursuits to enjoy the conviviality of the numerous friends who courted his company; or that drinking and dissipation became habitual to him. He was as deficient in point of prudence as he excelled in genius. His house was filled with respectable boarders; but as he lived too splendidly for an income at best but precarious, he became gradually involved in debt, and his affairs were still more embarrassed by the burden of a numerous family. Soon after he began to be involved in these difficulties, he suffered an additional loss in being deprived of the patronage of Dr Cullen, in consequence of a disagreement that had taken place between them. This enmity, which had for some time before secretly subsisted, probably from mutual jealousy, was at length excited into an open rupture; first, by Dr Cullen's not exerting his interest in procuring for Brown the theoretical chair of medicine, then vacant in consequence either of the death or resignation of Dr Alexander Monro Drummond; and, secondly, by his rejecting, some time after, Brown's petition for admittance into the Edinburgh Philosophical Society.

In 1776 Brown was elected president of the Medical Society; and the same honour was again conferred on him in 1780. He was led on, in the gradual manner he himself describes in his masterly preface to the *Elementa Medicinæ*, to the discovery of his new doctrine; which, on dropping all correspondence with his former friend and benefactor, he now, for the first time, began to illustrate in a course of public lectures; and in these he displayed equal ingenuity and philosophical profundity. Much about the time of which we now speak, he published the first edition of the *Elementa Medicinæ*; a work which certainly proves its author to have been a man of uncommon genius and originality of thought. The circumstances in which this work was composed reflect great honour on his abilities. He never retired to his study; but, totally absorbed in his own ideas, wrote with the greatest tranquillity amidst the noise of ten children, occasionally settling their childish differences.

In the year 1779, though he had studied medicine ten or twelve years at the university of Edinburgh, he was prevailed upon by his friends to take a degree at St Andrews, where he gave a conspicuous proof of his facility in Latin composition. He wrote a thesis, or inaugural dissertation, in the tavern while the cloth was laying for dinner; and one of his companions, who was

singing

Brown. singing beside him, having uttered a false note, or sung out of time, Mr Brown, in the middle of his writing, stopped to shew him how the song ought to be sung, and then instantly proceeded in his thesis.

His family having now become so numerous as to render keeping a boarding-house inconvenient, he had already for some time given it up, and depended for support entirely on his practice as a physician and his public lectures. At this time the disputes between the Cullenians and the Brunonians (as the young men now styled themselves) were carried on with such acrimony on both sides, in the different societies, that it was not unusual for them to terminate in duels; and there exists at this day, on the records of the Medical Society, a law which it was thought expedient to enact, by which a member who challenges another for any thing said in public debate incurs the penalty of expulsion.

Observing the students of medicine frequently to seek initiation into the mysteries of free-masonry, Dr Brown thought their youthful curiosity afforded him a chance of proselytes. In 1784, he instituted a meeting of that fraternity, and intitled it *the Lodge of the Roman Eagle*. The business was conducted in the Latin language, which he spoke with the same fluency as Scotch; and he displayed much ingenuity in turning into Latin all the terms used in masonry.

As the terms on which he lived with his brethren of the faculty were such that he obstinately avoided meeting them even in consultation, we may conclude that his own private practice was but limited. His friends affirmed, perhaps without sufficient proof, that cabals were formed against him, and every advantage taken of the errors he was led to commit by his own imprudence. After a long series of struggles, therefore, hoping to meet with that encouragement among the English of which he had been disappointed in his own country, he put in practice a plan upon which he had long meditated, and removed in 1786 with part of his family to London. Immediately on his arrival, an incident befel him, which Dr Beddoes says he has heard the late Mr Murray, bookseller in Fleet-street, relate as a proof of his simplicity. The peculiarity of his appearance as he moved along (a short square figure, with an air of dignity, in a black suit, which heightened the scarlet of his cheeks and nose) fixed the attention of some gentlemen in the street. They addressed him in the dialect of his country. His heart, heavy as it must have been, from the precariousness of his situation, and distance from his accustomed haunts, expanded at these agreeable sounds. A conversation ensued; and the parties, by common consent, adjourned to a tavern. Here the stranger was kindly welcomed to town; and, after the glass had circulated for a time, something was proposed by way of sober amusement—a game at cards, or whatever the Doctor might prefer. The Doctor had been too civilly treated to demur; but his purse was scantily furnished, and it was necessary to quit his new friends in search of a supply. Mr Murray was the person to whom he had recourse: the reader will not wonder that his interference should have spoiled the adventure.

A London sharper, of another denomination, afterwards tried to make advantage by the Doctor. This was an ingenious speculator in public medicines. He thought a composition of the most powerful stimulants

might have a run, under the title of *Dr Brown's exciting pill*; and, for the privilege of his name, offered him a sum in hand by no means contemptible, as well as a share of the contingent profits. Poor Brown, needy as he was, spurned at the proposal.

After this period, his life affords little variety of incident. Like Avicenna, his time seems to have been spent between his literary pursuits and his pleasures. A splendid manner of living, without an income to support it, had become habitual to him: The consequence was, that, from inability to discharge certain debts he had contracted, he was thrown into the king's bench prison; from which, however, he was, not long afterwards, released by the exertions of a few firm friends, particularly Mr Maddison of Charing-cross, a gentleman universally respected for his well-known benevolence. As a proof of the activity he was still capable of exerting, it will be sufficient to mention, that he accomplished the translation of his *Elementa*, with the addition of the supplementary notes, within 23 days, having been informed that a translation of the same was about to be published by another person.

Shortly before his death, the ambassador of the king of Prussia, in the name of his master, made Dr Brown an offer of a settlement in the court of Berlin; during the negotiation of which he was unexpectedly cut off by an apoplexy early in the morning of the 7th of October 1788, the day succeeding that on which he had delivered to a company of thirteen gentlemen the greater part of the introductory lecture to his second course. At his death, he was between 52 and 53 years of age. His remains were interred in the church-yard of St James's Picadilly; and the only monument left behind him to transmit his name to posterity is his own works; which, when personal prejudice no longer shall prevail against their ingenious author, cannot fail to procure him all that deserved celebrity which they have already, in part, obtained in the different countries of Europe.

In 1787, he published his "Observations," without his name, which he afterwards, however, refers to in the Elements as his own. The "Enquiry," said to be written by Dr Jones, and which was composed in as short a time as the generality of men would transcribe a work of its extent, we can affirm, from undoubted authority, to be his production.

This sketch of the life of the unfortunate Dr Brown would be of very little value if not followed by a view of his system; but to give a complete view of that system would far exceed the limits within which, in a work like this, such articles must be confined. We trust, therefore, that our readers will be satisfied with an abstract; and as we are neither the partisans nor opponents of the Doctor, and not very partial to any medical system whatever, we shall content ourselves with inserting, in this place, the view which Dr Beddoes has given of Dr Brown's fundamental propositions in the valuable observations which he has prefixed to his edition of the Elements of Medicine.

"The varied structure of organized beings (says Dr Beddoes), it is the business of anatomy to explain. Consciousness, assisted by common observation, will distinguish animated from inanimate bodies with precision more than sufficient for all the ends of medicine. The cause of gravitation has been left unexplored by all prudent

Brown.

dent philosophers; and Brown, avoiding all useless disquisition concerning the cause of vitality, confines himself to the phenomena which this great moving principle in nature may be observed to produce. His most general propositions are easy of comprehension.

“ 1. To every animated being is allotted a certain portion only of the quality or principle on which the phenomena of life depend. This principle is denominated *excitability*.

“ 2. The excitability varies in different animals, and in the same animal at different times. As it is more intense, the animal is more vivacious or more susceptible of the action of exciting powers.

“ 3. Exciting powers may be referred to two classes. 1. External; as heat, food, wine, poisons, contagions, the blood, secreted fluids, and air. 2. Internal; as the functions of the body itself, muscular exertion, thinking, emotion, and passion.

“ 4. Life is a forced state; if the exciting powers are withdrawn, death ensues as certainly as when the excitability is gone.

“ 5. The excitement may be too great, too small, or in just measure.

“ 6. By too great excitement, weakness is induced, because the excitability becomes defective; this is *indirect debility*: when the exciting powers and stimulants are withheld, weakness is induced; and this is *direct debility*. Here the excitability is in excess.

“ 7. Every power that acts on the living frame is stimulant, or produces excitement by expending excitability. Thus, although a person accustomed to animal food may grow weak if he lives upon vegetables, still the vegetable diet can only be considered as producing an effect, the same in kind with animals, though inferior in degree. Whatever powers, therefore, we imagine, and however they vary from such as are habitually applied to produce due excitement, they can only weaken the system by urging it into too much motion, or suffering it to sink into languor.

“ 8. Excitability is seated in the medullary portion of the nerves, and in the muscles. As soon as it is anywhere affected, it is immediately affected everywhere; nor is the excitement ever increased in a part, while it is generally diminished in the system; in other words, different parts can never be in opposite states of excitement.

“ I have already spoken of an illustration, drawn up by Mr Christie from a familiar operation, to facilitate the conception of Brown's fundamental positions. I introduce it here as more likely to answer its purpose than if separately placed at the end of my preliminary observations. ‘ Suppose a fire to be made in a grate, filled with a kind of fuel not very combustible, and which could only be kept burning by means of a machine containing several tubes, placed before it, and constantly pouring streams of air into it. Suppose also a pipe to be fixed in the back of the chimney, through which a constant supply of fresh fuel was gradually let down into the grate, to repair the waste occasioned by the flame, kept up by the air machine.

‘ The grate will represent the human frame; the fuel in it, the matter of life—the excitability of Dr Brown, and the sensorial power of Dr Darwin; the tube behind, supplying fresh fuel, will denote the power of all living systems, constantly to regenerate or reproduce excitability; while the air machine, of several tubes,

denotes the various stimuli applied to the excitability of the body; and the flame drawn forth in consequence of that application represents life, the product of the exciting powers acting upon the excitability.

‘ As Dr Brown has defined life to be a *forced state*, it is fitly represented by a flame forcibly drawn forth from fuel little disposed to combustion, by the constant application of streams of air poured into it from the different tubes of a machine. If some of these tubes are supposed to convey pure or dephlogisticated air, they will denote the highest class of exciting powers, opium, musk, camphor, spirits, wine, tobacco, &c. the diffusible stimuli of Dr Brown, which bring forth for a time a greater quantity of life than usual, as the blowing in of pure air into a fire will temporarily draw forth an uncommon quantity of flame. If others of the tubes be supposed to convey common or atmospheric air, they will represent the ordinary exciting powers, or stimuli, applied to the human frame, such as heat, light, air, food, drink, &c. while such as convey impure and inflammable air may be used to denote what have formerly been termed sedative powers, such as poisons, contagious miasmata; foul air, &c.

‘ The reader will now probably be at no loss to understand the seeming paradox of the Brunonian system; that food, drink, and all the powers applied to the body, though they support life, yet consume it; for he will see that the application of these powers, though it brings forth life, yet at the same time it wastes the excitability or matter of life, just as the air blown into the fire brings forth more flame, but wastes the fuel or matter of fire. This is conformable to the common saying, “ the more a spark is blown, the brighter it burns, and the sooner it is spent.” A Roman poet has given us, without intending it, an excellent illustration of the Brunonian system, when he says,

“ *Balnea, vina, Venus, consumunt corpora nostra;*
“ *Sed vitam faciunt balnea, vina, Venus.*

“ Wine, warmth, and love, our vigour drain;
“ Yet wine, warmth, love, our life sustain.”

Or to translate it more literally,

“ Baths, women, wine, exhaust our frame;
“ But life itself is drawn from them.”

‘ Equally easy will it be to illustrate the two kinds of debility, termed *direct* and *indirect*, which, according to Brown, are the cause of all diseases. If the quantity of stimulus or exciting power is proportioned to the quantity of excitability, that is, if no more excitement is drawn forth than is equal to the quantity of excitability produced, the human frame will be in a state of health, just as the fire will be in a vigorous state when no more air is blown in than is sufficient to consume the fresh supply of fuel constantly poured down by the tube behind. If a sufficient quantity of stimulus is not applied, or air not blown in, the excitability in the man, and the fuel in the fire, will accumulate, producing direct debility; for the man will become weak, and the fire low. Carried to a certain degree, they will occasion death to the first, and extinction to the last. If, again, an over proportion of stimulus be applied, or too much air blown in, the excitability will soon be wasted, and the matter of fuel almost spent. Hence will

Brown.

Brown.

will arise indirect debility, producing the same weakness in the man, and lowness in the fire, as before, and equally terminating, when carried to a certain degree, in death and extinction.

‘As all the diseases of the body, according to Dr Brown, are occasioned by direct or indirect debility, in consequence of too much or too little stimuli, so all the defects of the fire must arise from direct or indirect lowness, in consequence of too much or too little air blown into it. As Brown taught that one debility was never to be cured by another, but both by the more judicious application of stimuli, so will be found the case in treating the defects of the fire. If the fire has become low, or the man weak, by the want of the needful quantity of stimulus, more must be applied, but very gently at first, and increased by degrees, lest a strong stimulus applied to the accumulated excitability should produce death; as in the case of a limb benumbed with cold (that is, weakened by the accumulation of its excitability in consequence of the abstraction of the usual stimulus of heat), and suddenly held to the fire, which we know from experience is in danger of mortification; or as in the case of the fire becoming very low by the accumulation of the matter of fuel, when the feeble flame, assailed by a sudden and strong blast of air, would be overpowered and put out, instead of being nourished and increased. Again, if the man or the fire have been rendered indirectly weak, by the application of too much stimulus, we are not suddenly to withdraw the whole, or even a great quantity of the exciting powers or air, for then the weakened life and diminished flame might sink entirely; but we are by little and little to diminish the overplus of stimulus, so as to enable the excitability, or matter of fuel, gradually to recover its proper proportion. Thus a man who has injured his constitution by the abuse of spirituous liquors is not suddenly to be reduced to water alone, as is the practice of some physicians, but he is to be treated as the judicious Dr Pitcairn of Edinburgh is said to have treated a Highland chieftain, who applied to him for advice in this situation. The Doctor gave him no medicines, and only exacted a promise of him, that he would every day put in as much wax into the wooden *queich*, out of which he drank his whisky, as would receive the impression of his arms. The wax thus gradually accumulating, diminished daily the quantity of the whisky, till the whole *queich* was filled with wax; and the chieftain was thus gradually, and without injury to his constitution, cured of the habit of drinking spirits.

‘These analogies might be pursued farther; but my object is solely to furnish some general ideas, to prepare the reader for entering more easily into the Brunonian theory, which I think he will be enabled to do after perusing what I have said. The great excellence of that theory, as applied, not only to the practice of physic, but to the general conduct of the health, is, that it impresses on the mind a sense of the impropriety and danger of going from one extreme to another. The human frame is capable of enduring great varieties, if time be given it to accommodate itself to different states. All the mischief is done in the transition from one state to another. In a state of low excitement, we are not rashly to induce a state of high excitement; nor when elevated to the latter, are we suddenly to descend to the former, but step by step, and as one who from the top

of a high tower descends to the ground. From hasty and violent changes the human frame always suffers; its particles are torn asunder, its organs injured, the vital principle impaired, and disease, often death, is the inevitable consequence.

‘I have only to add, that though in this illustration of the Brunonian system (written several years ago), I have spoken of a tube constantly pouring in fresh fuel, because I could not otherwise convey to the reader a familiar idea of the power possessed by all living systems, to renew their excitability when exhausted; yet it may be proper to inform the student, that Dr Brown supposed every living system to have received at the beginning its determinate portion of excitability; and, therefore, although he spoke of the exhaustion, augmentation, and even renewal of excitability, I do not think it was his intention to induce his pupils to think of it as a kind of fluid substance existing in the animal, and subject to the law by which such substances are governed. According to him, excitability was an unknown *somewhat*, subject to peculiar laws of its own, and whose different states we were obliged to describe (though inaccurately) by terms borrowed from the qualities of material substances.’

‘The Brunonian system has frequently been charged with promoting intemperance. The objection is serious; but the view already given of its principles shews it to be groundless. No writer had insisted so much upon the dependence of life on external causes, or so strongly stated the inevitable consequences of excesses. And there are no means of promoting morality upon which we can rely, except the knowledge of the true relations between man and other beings or bodies. For by this knowledge we are directly led to shun what is hurtful, and pursue what is salutary. And in what else does moral conduct, as far as it regards the individual, consist? It may be said that the author’s life disproves the justness of this representation: his life, however, only shews the superior power of other causes, and of bad habits in particular; and I am ready to acknowledge the little efficacy of instruction when bad habits are formed. Its great use consists in preventing their formation; for which reason popular instruction in medicine would contribute more to the happiness of the human species, than the complete knowledge of every thing which is attempted to be taught in education, as it is conducted at present. But though the principles of the system in question did not correct the propensities of its inventor, it does not follow that they tend to produce the same propensities in others.’

BRUCE (James, Esq; F. R. S.), the celebrated Abyssinian traveller, was born, 1730, at Kinnaird house, in the parish of Larbert and county of Stirling. His descent by both parents was ancient and honourable; and of that descent he was, perhaps, too proud. His grandfather was — Hay, Esq; of Woodcockdale, in the county of Linlithgow, who, marrying Miss Bruce, the heiress of Kinnaird, gave the name of *Bruce* to all his descendants.

Perhaps this change of name may have taken place in obedience to the deed by which the estate of Kinnaird was settled on Mrs Hay’s children; but it is a change which, in a country like Scotland, where antiquity of descent is highly valued, any man would voluntarily have adopted, who had married the heiress of
such

Brown,
Bruce.

such a family. The Bruces of Kinnaird had been in possession of that estate for three centuries: they were descended from a younger son of Robert de Bruce, the competitor with Baliol for the crown of Scotland. It would readily occur, that the knowledge of such a descent would be best preserved by continuing the name of their great ancestor; and we have reason to believe, that the subject of this memoir was not much delighted when put in mind, as he frequently was, that, though the heir of the line, he was not the *male* heir of that branch of the illustrious family.

As he was allied to royalty by his father and grandmother, through his mother he was related to some of the most respectable families in the kingdom. She was the daughter of James Graham, Esq; of Airth, dean of the faculty of advocates, and judge of the high court of admiralty in Scotland, by Marion, daughter of James Hamilton Esq; of Pencaitland; and to a man of our traveller's turn of mind, there can be no doubt but that it must have afforded much satisfaction to think, that no family ranks higher in Scotland than those of Bruce, Graham, and Hamilton. In him, however, it was weakness to be proud, if indeed he was proud, of family; for the talents bestowed upon him by nature, or, to speak more properly, by nature's God, would have made him great though he had been born on a dunghill. He would indeed have been, in all probability, much greater than he was, had he not been in possession of the phantom of birth to gratify much of his ambition; for the facility with which he mastered every study in which he engaged, would have carried him quickly to the top of the most honourable profession.

Mr Bruce was instructed in grammatical learning at the school of Harrow on the Hill, in the county of Middlesex, where he gave the most unequivocal proofs of genius, and acquired a very considerable knowledge of the Greek and Latin languages. It was customary with him to perform, not only his own exercises, but also the exercises of such of his companions as were not equal to the task themselves. Among these was his maternal uncle, who was frequently indebted to his assistance, and, on one occasion, produced a copy of verses of his composition, which excited, not only the applause, but the admiration of their master. Mr Graham, who was but a few months older than Mr Bruce, had, for some transgression (we know not what), been punished, as boys in the great schools in England are often punished, by having a task set him, which he soon found himself unable to perform. His nephew desired him to be under no uneasiness, promising to furnish him with the verses before the time at which they were to be given in. He was as good as his word; but the matter of the school soon discovering that they were not the performance of Mr Graham, exclaimed, that the author of these verses, whoever he was, might apply to himself the words of Horace,

— *Sublimi feriam sidera vertice.*

While Mr Bruce was at Harrow, and for a year or two after he had left it, he was of a very delicate frame, and appeared to his friends to be threatened with a consumption. The truth is, that he was uncommonly tall for his age, and felt all the feebleness of joints and other bodily weaknesses to which overgrown boys are generally subject. His father intended him

for the profession of the law; and, upon his return from Harrow, he was entered into the university of Edinburgh, where he went through a regular course of study to fit him for being enrolled in the body of advocates: but for some reason, which we do not perfectly know, he relinquished the study of law for the pursuits of trade; and, going to London, entered into partnership with a wine merchant of the name of Allen, whose daughter he married.

That lady falling into a bad state of health, Mr Bruce took her abroad, in hopes that travelling would be attended with beneficial effects; but in these he was disappointed, as she died within a year after her marriage. He was induced, in order to dispel his grief, to continue his travels; during which his father dying (at Edinburgh, 4th May 1758), the inheritance of his ancestors devolved upon him, and he returned to Britain. Some of his subsequent transactions shall now be related in his own words.

“Every one will remember that period, so glorious to Britain, the latter end of the ministry of the late earl of Chatham. I was then returned from a tour through the greatest part of Europe, particularly through the whole of Spain and Portugal, between whom there was then the appearance of an approaching war.

“I was about to retire to a small patrimony I had received from my ancestors, in order to embrace a life of study and reflection, nothing more active appearing within my power, when chance threw me unexpectedly into a very short and very desultory conversation with Lord Chatham.

“It was a few days after this that Mr Wood, then under-secretary of state, my zealous and sincere friend, informed me that Lord Chatham intended to employ me upon a particular service; that, however, I might go down for a few weeks to my own country to settle my affairs, but, by all means, to be ready upon a call. Nothing could be more flattering to me than such an offer, when so young; to be thought worthy by Lord Chatham of any employment, was doubly a preference. No time was lost on my side; but just after receiving orders to return to London, his lordship had gone to Bath, and resigned his office.

“This disappointment, which was the more sensible to me that it was the first I had met with in public life, was promised to be made up to me by Lord Egremont and Mr George Grenville. The former had been long my friend; but unhappily he was then far gone in a lethargic indisposition, which threatened, and did very soon put a period to his existence. With Lord Egremont's death my expectations vanished. Further particulars are unnecessary; but I hope that, at least in part, they remain in that breast where they naturally ought to be, and where I shall ever think, not to be long forgotten, is to be rewarded.

“Seven or eight months were passed in an expensive and fruitless attendance in London, when Lord Halifax was pleased, not only to propose, but to plan for me a journey of considerable importance, and which was to take up several years. His lordship said, that nothing could be more ignoble than, at such a time of life, at the height of my reading, health, and activity, I should, as it were, turn peasant, and voluntarily bury myself in obscurity and idleness; that though war was now drawing fast to an end, full as honourable a competition remained

mained among men of spirit, which should acquit themselves best in the dangerous line of useful adventure and discovery.

“ He observed, that the coast of Barbary, which might be said to be just at our door, was yet but partially explored by Dr Shaw, who had only illustrated (very judiciously indeed) the geographical labours of Sanfon; that neither Dr Shaw nor Sanfon had been, or pretended to be, capable of giving the public any detail of the large and magnificent remains of ruined architecture, which they both vouch to have seen in great quantities, and of exquisite elegance and perfection, all over the country. Such had not been their study, yet such was really the taste that was required in the present times. He wished, therefore, that I should be the first, in the reign just now beginning, to set an example of making large additions to the royal collection; and he pledged himself to be my support and patron, and to make good to me, upon this additional merit, the promises which had been held forth to me by former ministers for other services.

“ The discovery of the source of the Nile was also a subject of these conversations, but it was always mentioned to me with a kind of diffidence, as if to be expected from a more experienced traveller. Whether this was but another way of exciting me to the attempt I shall not say; but my heart, in that instant, did me justice to suggest, that this too was either to be achieved by me, or to remain as it had done for these last 2000 years, a defiance to all travellers, and an opprobrium to geography.

“ Fortune seemed to enter into this scheme. At the very instant, Mr Aspinwall, very cruelly and ignominiously treated by the dey of Algiers, had resigned his consulship, and Mr Ford a merchant, formerly the dey’s acquaintance, was named in his place. Mr Ford was appointed, and, dying a few days after, the consulship became vacant. Lord Halifax pressed me to accept of this as containing all sorts of conveniences for making the proposed expedition.

“ This favourable event finally determined me. I had all my life applied unweariedly, perhaps with more love than talent, to drawing, the practice of mathematics, and especially that part necessary to astronomy. The transit of Venus was at hand. It was certainly known that it would be visible once at Algiers, and there was great reason to expect it might be twice. I had furnished myself with a large apparatus of instruments, the completest of their kind, for the observation. In the choice of these, I had been assisted by my friend Admiral Campbell, and Mr Ruffel secretary to the Turkey Company: every other necessary had been provided in proportion. It was a pleasure now to know that it was not from a rock or a wood, but from my own house at Algiers, I could deliberately take measures to place myself in the list of men of science of all nations, who were then preparing for the same scientific purpose.

“ Thus prepared, I set out for Italy, through France; and though it was in time of war, and some strong objections had been made to particular passports, solicited by our government from the French secretary of state, Monsieur de Choiseul most obligingly waved all such exceptions with regard to me, and most politely assured me, in a letter accompanying my passport, that those difficulties did not in any shape regard me, but

that I was perfectly at liberty to pass through, or remain in, France with those that accompanied me, without limiting their number, as short or as long a time as should be agreeable to me.

“ On my arrival at Rome, I received orders to proceed to Naples, there to await his majesty’s further commands. Sir Charles Saunders, then with a fleet before Cadiz, had orders to visit Malta before he returned to England. It was said that the grand-master of that order had behaved so improperly to Mr Harvey (afterwards Lord Bristol) in the beginning of the war, and so partially and unjustly between the two nations in the course of it, that an explanation on our part was become necessary. The grand-master no sooner heard of my arrival at Naples, than, guessing the errand, he sent off Chevalier Mazzini to London, where he at once made his peace and his compliments to his majesty upon his accession to the throne.

“ Nothing remained now but to take possession of my consulship. I returned, without loss of time, to Rome, and from thence to Leghorn, where, having embarked on board the Montreal man of war, I proceeded to Algiers.

“ While at Naples, I received from slaves, redeemed from the province of Constantine, accounts of magnificent ruins they had seen while traversing that country with their master the Bey. I saw the absolute necessity there was for assistance, without which it was impossible for any one man, however diligent and qualified, to do any thing but bewilder himself. All my endeavours, however, had hitherto been unsuccessful to persuade any Italian to put himself wilfully into the hands of a people constantly looked upon by them in no better light than pirates. At last Mr Lumisden, by accident, heard of a young man who was then studying architecture at Rome, a native of Bologna, whose name was Luigi Balugani. I can appeal to Mr Lumisden as to the extent of this person’s practice and knowledge, and that he knew very little when first sent to me. In the twenty months which he staid with me at Algiers, by assiduous application to proper subjects under my instruction, he became a very considerable help to me, and was the only one that ever I made use of, or that attended me for a moment, or ever touched one representation of architecture in any part of my journey.”

Our traveller, when in Spain, had endeavoured to find access to that immense collection of Arabic manuscripts which were perishing in the dust of the escorial; but in vain. “ All my success (says he) in Europe terminated in the acquisition of those few printed Arabic books that I had found in Holland; and these were rather biographers than general historians, and contained little in point of general information. The study of these, however, and of Maracci’s Koran, had made me a very tolerable Arab; a great field was opening before me in Africa to complete a collection of manuscripts, an opportunity which I did not neglect.

“ After a year spent at Algiers, constant conversation with the natives while abroad, and with my manuscripts within doors, had qualified me to appear in any part of the continent without the help of an interpreter. Ludolf had assured his readers, that the knowledge of any oriental language would soon enable them to acquire the Ethiopic; and I needed only the same number of books to have made my knowledge of that language.

Bruce.

guage go hand in hand with my attainments in the Arabic. My immediate prospect of setting out on my journey to the inland parts of Africa had made me double my diligence; night and day there was no relaxation from these studies, although the acquiring any single language had never been with me either an object of time or difficulty."

At Algiers Mr Bruce was detained longer than he expected, in consequence of a dispute with the Dey concerning Mediterranean passes. This being adjusted, he proceeded to Mahon, and from Mahon to Carthage. He next visited Tunis and Tripoli, and travelled over the interior parts of these states. At Bengazi, a small town on the Mediterranean, he suffered shipwreck, and with extreme difficulty saved his life, though with the loss of all his baggage. He afterwards sailed to the isles of Rhodes and Cyprus, and proceeding to Asia Minor, travelled through a considerable part of Syria and Palestine, visiting Hassia, Latikea, Aleppo, and Tripoli; near which last city he was again in imminent danger of perishing in a river. The ruins of Palmyra and Baalbec were next carefully surveyed and sketched by him; and his drawings of these places are deposited in the king's library at Kew; "the most magnificent present in that line," to use his own words, "ever made by a subject to his sovereign."

It is much to be regretted that Mr Bruce published no particular account of these various journeys; from the nature of the places visited, and the abilities of the man, much curious and useful information might have been expected. Some manuscript accounts of different parts of them are said to have been left by him, but whether in such a state as to be fit for publication, we have not learned.

In these various travels some years were passed; and Mr Bruce now prepared for the grand expedition, the accomplishment of which had ever been nearest his heart, the discovery of the sources of the Nile. In the prosecution of that dangerous object, he left Sidon on the 15th of June 1768, and arrived at Alexandria on the 20th of that month. He proceeded from thence to Cairo, where he continued to the 12th of December following, when he embarked on the Nile; and in a very extraordinary boat, called a *canja*, of which he says the main-sail yard was about 200 feet in length, he sailed up that river as far as Syene, visiting in the course of his voyage the ruins of Thebes, and the place where Memphis once stood, now known by the name of *Metrahenny*. Leaving Kenne on the Nile, 16th February 1769, he crossed the desert of the Thebaid to Cossair on the Red Sea, and arrived at Jidda on the 3d of May. In Arabia Felix he remained, not without making several excursions, till the 3d of September, when he sailed from Loheia, and arrived on the 19th at Masuah, where he was detained near two months by the treachery and avarice of the Naybe of that place. It was not till the 15th of November that he was allowed to quit Arkeeko,

near Masuah; and he arrived on the 15th of February 1770 at Gondar, the capital of Abyssinia, where he ingratiated himself with the most considerable persons of both sexes belonging to the court. This he accomplished by being a physician in the city, a soldier in the field, a courtier everywhere, demeaning himself as conscious that he was not unworthy of being a companion to the first of their nobility, and the king's guest, which is there a character, as it was with eastern nations of old, to which a certain sort of consideration is due. "To this I may add (says he), that, being in the prime of life, of no ungracious figure, having an accidental knack, which is not a trifle, of putting on the dress, and speaking the language easily and gracefully, I cultivated, with the utmost assiduity, the friendship of the fair sex, by the most modest and respectful distant attendance and obsequiousness in public, abating just as much of that in private as suited their humours and inclination;" and jealousy being a passion unknown in Abyssinia, he thus acquired from the ladies great support at court.

Several months were employed in attendance on the king, and in an unsuccessful expedition round the lake of Dambea. Towards the end of October Mr Bruce set out for the sources of the Nile; at which long desired spot he arrived on the 14th of November; and his feelings on the accomplishment of his wishes cannot better be expressed than in his own words:

"It is easier to guess than to describe the situation of my mind at that moment; standing in that spot which had baffled the genius, industry, and inquiry, of ancients and moderns for the course of near 3000 years. Kings had attempted this discovery at the head of armies, and each expedition was distinguished from the last only by the difference of the numbers which had perished, and agreed alone in the disappointment which had uniformly, and without exception, followed them all. Fame, riches, and honour, had been held out for a series of ages to every individual of those myriads whose princes commanded, without having produced one man capable of gratifying the curiosity of his sovereign, or wiping off this stain upon the enterprise and abilities of mankind, or adding this desideratum for the encouragement of geography. Though a mere private Briton, I triumphed here in my own mind over kings and their armies; and every comparison was leading nearer and nearer to the presumption, when the place itself where I stood, the object of my vain glory, suggested what depressed my short-lived triumphs."

If these triumphs were short-lived, they were equally ill-founded: for if the source of the Nile was seen by Mr Bruce, there can be no doubt of its having been likewise seen by the Portuguese jesuits. Of this we have elsewhere brought forward sufficient proof; and the candid reader, who shall take the trouble to compare the extract printed at the bottom of this page (A), with our traveller's account of these coy fountains, as it stands

(A) "In the eastern part of this kingdom, on the declivity of a mountain, whose descent is so easy that it seems a beautiful plain, is that source of the Nile which has been sought after at so much expence of labour, and about which such a variety of conjectures hath been formed without success. This spring, or rather these two springs, are two holes, each about two feet diameter, a stone's cast distant from each other. The one is about five feet and an half in depth, at least we could not get our plummet farther, perhaps because it was stopped by roots,

Bruce.

Bruce. stands in his own book or in our article NILE (*Encycl.*), will be convinced that it was ridiculous in Mr Bruce, and is equally ridiculous in his friends, to pretend that he discovered what had baffled the genius of inquiry for the course of near 3000 years.

It was not, however, the consciousness of having been anticipated by the jesuits (for these he without ceremony calls a set of liars), but the prospect of danger to be encountered on his return to Europe, that cast such a damp on his present enjoyment. "I was but a few minutes (saye he) arrived at the source of the Nile, through numberless dangers and sufferings, the least of which would have overwhelmed me, but for the continual goodness and protection of Providence; I was, however, but then half through my journey, and all those dangers which I had already passed awaited me again on my return. I found a despondency gaining ground fast upon me, which blasted the crown of laurels I had too rashly woven for myself."

When he returned to rest the night of that discovery, repose was sought for in vain. "Melancholy reflections upon my present state, the doubtfulness of my return in safety, were I permitted to make the attempt, and the fears that even this would be refused, according to the rule observed in Abyssinia with all travellers who have once entered the kingdom; the consciousness of the pain that I was then occasioning to many worthy individuals, expecting daily that information concerning my situation which it was not in my power to give them: some other thoughts, perhaps still nearer the heart than those, crowded upon my mind, and forbade all approach of sleep.

"I was, at that very moment, in possession of what had for many years been the principal object of my ambition and wishes; indifference which, from the usual infirmity of human nature, follows, at least for a time, complete enjoyment, had taken place of it. The marsh, and the fountains, upon comparison with the rise of many of our rivers, became now a trifling object in my sight. I remembered that magnificent scene in my own native country, where the Tweed, Clyde, and Annan, rise in one hill; three rivers I now thought not inferior to the Nile in beauty, preferable to it in the cultivation of those countries through which they flow; superior, vastly superior, to it in the virtues and qualities of the inhabitants, and in the beauty of its flocks, crowding its pastures in peace, without fear or violence from man or beast. I had seen the rise of the Rhine and Rhone, and the more magnificent sources of the Soane; I began, in my sorrow, to treat the inquiry

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about the source of the Nile as a violent effort of a dis-tempered fancy.

‘What’s Hecuba to him, or he to Hecuba,
‘That he should weep for her?’

Grief and despondency now rolling upon me like a torrent, relaxed, not refreshed, by unquiet and imperfect sleep, I started from my bed in the utmost agony; I went to the door of my tent, every thing was still; the Nile, at whose head I stood, was not capable either to promote or to interrupt my slumbers, but the coolness and serenity of the night braced my nerves, and chased away those phantoms that while in bed had oppressed and tormented me.

"It was true that numerous dangers, hardships, and sorrows, had beset me through this half of my excursion; but it was still as true, that another Guide, more powerful than my own courage, health, or understanding, if any of them can be called man's own, had uniformly protected me in all that tedious half. I found my confidence not abated, that still the same Guide was able to conduct me to my wished-for home. I immediately resumed my former fortitude, considered the Nile as indeed no more than rising from springs as all other rivers do, but widely differing in this, that it was the palm for 3000 years held out to all the nations of the world as a *detur dignissimo*, which in my cool hours I had thought was worth the attempting at the risk of my life, which I had long either resolved to lose, or lay this discovery a trophy in which I could have no competitor, for the honour of my country, at the feet of my sovereign, whose servant I was."

How unworthy is this ranting reflection of the greatness of mind which Mr Bruce on other occasions unquestionably displayed! Had he indeed been the first European who discovered those pitiful holes from which the Nile is said to flow, his merit would not have consisted in travelling from Gondar to the village Geesh, and viewing the fountains which are at that village the objects of idolatrous adoration, but in the address with which he contrived to make himself the favourite of all the factions which agitated a barbarous and almost inhuman nation. In managing those factions, he was indeed great; but he seems to have valued himself more upon looking at three springs, of which it is far from being certain that they are the sources of the Nile (see NILE in this *Suppl.*), and of which two had certainly been examined more than a century before he was born, by different missionaries from the kingdom of Portugal! This, however, he calls the object of his wishes;

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roots, for the whole place is full of trees: of the other, which is somewhat less, with a line of ten feet, we could find no bottom, and were assured by the inhabitants that none ever had been found. It is believed here that these springs are the vents of a great subterraneous lake; and they have this circumstance to favour their opinion, that the ground is always moist, and so soft that the water boils up under foot as one walks upon it. Such is the ground round about these fountains. At a little distance to the south is a village named *Guix* (the *Geesh* of Mr Bruce), through which the way lies to the top of the mountain, whence the traveller discovers a vast extent of land, which appears like a deep valley, though the mountain rises so imperceptibly, that those who go up or down it are scarce sensible of any declivity."—*Johnson's Translation of Father Lobo's Voyage to Abyssinia*, Chap. X.

The only difference between Lobo's and Bruce's account of these fountains worthy of notice is, that the former found but *two*, while the latter found *three* holes; but Bruce says expressly, that the holes are partly artificial; and Lobo's description of them indicates the same thing. It is therefore not improbable that there may now be four or five holes.

Bruce. and having now accomplished it, he bent his thoughts on his return to his native country.

He arrived at Gondar on the 19th November 1770; but found, after repeated solicitations, that it was by no means an easy task to obtain permission to quit Abyssinia. A civil war in the mean time breaking out (no uncommon occurrence in that barbarous country), several engagements took place between the king's forces and the troops of the rebels, particularly three actions at a place called Serbraxos on the 19th, 20th, and 23d of May 1771. In each of them Mr Bruce acted a considerable part; and for his valiant conduct in the second received, as a reward from the king, a chain of gold, of 184 links, each link weighing $3\frac{1}{2}$ dwts. or somewhat more than 2½ lbs. troy in all. At Gondar, after these engagements, he again preferred the most earnest entreaties to be allowed to return home, entreaties which were long resisted; but his health at last giving way, from the anxiety of his mind, the king consented to his departure, on condition of his engaging by oath (B) to return to him in the event of his recovery, with as many of his kindred as he could engage to accompany him.

After a residence of nearly two years in that wretched country, Mr Bruce left Gondar on the 16th of December 1771, taking the dangerous way of the desert of Nubia, in place of the more easy road of Mafuah, by which he entered Abyssinia. He was induced to take this route from his knowledge and former experience of the cruel and savage temper of the Naybe of Mafuah. Arriving at Teawa the 21st March 1772, he had the misfortune to find the Shekh Fidele of Atbara, the counterpart of the Naybe of Mafuah in every bad quality: by his intrepidity and prudence, however, and by making good use of his foreknowledge of an eclipse of the moon, which happened on the 17th of April, he was permitted to depart next day, and he arrived at Sennaar on the 29th of the same month.

Mr Bruce was detained upwards of four months at that miserable and inhospitable place; the inhabitants of which he describes in these expressive words: "War and treason seem to be the only employment of these horrid people, whom heaven has separated by almost impassable deserts from the rest of mankind, confining them to an accursed spot, seemingly to give them an earnest in time of the only other worse which he has reserved to them for an eternal hereafter." This delay was occasioned by the villany of those who had undertaken to supply him with money; but at last, by disposing of 178 links of his gold chain, the well-earned trophy of Serbraxos, he was enabled to make preparation for his dangerous journey through the deserts of Nubia.

He left Sennaar on the 5th of September, and arrived on the 3d of October at Chendi, which he quitted on the 20th, and travelled through the desert of Gooz, to which village he came on the 26th of October. On the 9th of November he left Gooz, and entered upon the most dreadful and dangerous part of his

Bruce. journey; the perils attending which he has related with a power of pencil not unworthy of the greatest masters. All his camels having perished, Mr Bruce was under the necessity of abandoning his baggage in the desert, and with the greatest difficulty reached Assouan upon the Nile on the 29th of November.

After some days rest, having procured fresh camels, he returned into the desert, and recovered his baggage, among which is particularly to be remarked a quadrant (of three feet radius) supplied by Louis XV. from the Military Academy at Marfeilles; by means of which noble instrument, now deposited in the Museum at Kinnaid, Mr Bruce was enabled with precision and accuracy to fix the relative situations of the several remote places he visited.

On the 10th of January 1773, after more than four years absence, he arrived at Cairo, where, by his manly and generous behaviour, he so won the heart of Mahomet Bey, that he obtained a firman, permitting the commanders of English vessels belonging to Bombay and Bengal to bring their ships and merchandise to Suez, a place far preferable in all respects to Jidda, to which they were formerly confined. Of this permission, which no European nation could ever before acquire, many English vessels have since availed themselves; and it has proved peculiarly useful both in public and private dispatches. Such was the worthy conclusion of his memorable journey through the desert; a journey which, after many hardships and dangers, terminated in obtaining this great national benefit.

At Cairo Mr Bruce's earthly career had nearly been concluded by a disorder in his leg, occasioned by a worm in the flesh. This accident kept him five weeks in extreme agony; and his health was not re-established till a twelvemonth afterwards, at the baths of Porretta in Italy. On his return to Europe, Mr Bruce was received with all the admiration due to so exalted a character. After passing some considerable time in France, particularly at Montbard, with his friend the Comte de Buffon, by whom he was received with much hospitality, and is mentioned with great applause, he at last revisited his native country, from which he had been upwards of twelve years absent.

It was now expected that he would take the earliest opportunity of giving to the world a narrative of his travels, in which the public curiosity could not but be deeply interested. But several circumstances contributed to delay the publication; and what these were will be best related in his own words:

"My friends at home gave me up for dead; and as my death must have happened in circumstances difficult to have been proved, my property became as it were a *hereditas jacens*, without an owner, abandoned in common to those whose original title extended no further than temporary possession.

"A number of law-suits were the inevitable consequences of this upon my return. To these disagreeable avocations, which took up much time, were added others still more unfortunate. The relentless ague, caught at Bengazi,

(B) With regard to this oath, Mr Bruce says, that he hopes the difficulty of performing it extinguished the sin of breaking it; and that, at any rate, it being merely personal, his engagement to return ceased with the death of the king, of which he received intelligence during his stay at Sennaar.

Bruce. Bengazi, maintained its ground, at times, for a space of more than 16 years, though every remedy had been used, but in vain; and what was worst of all, a lingering distemper had seriously threatened the life of a most near relation (his second wife), which, after nine years constant alarm, where every duty bound me to attention and attendance, conducted her at last, in very early life, to her grave."

Amidst the anxiety and the distress thus occasioned, Mr Bruce was by no means neglectful of his private affairs. He considerably improved his landed property, enclosing and cultivating the waste grounds, and he highly embellished his paternal seat, making many additions to the house, one in particular of a noble museum, filled with the most precious stores of oriental literature, large collections of drawings made, and curious articles obtained, during his far extended peregrinations. An excellent stratum of coal at Kinnaird drew much of his attention: he erected steam engines of the most approved construction, and placed his coalery on such a footing that, at the period of his decease, it produced about 2000l. a-year.

The termination of some law-suits, and of other business, which had occupied much of his time, having at length afforded leisure to Mr Bruce to put his materials in order, his greatly desired and long expected work made its appearance in 1790, in five large quarto volumes, embellished with plates and charts. It is unnecessary, and might be tedious, to enter at present into any critic or analysis of this celebrated work. It is universally allowed to be replete with much curious and useful information; and to abound in narratives which at once excite our admiration and interest our feelings. The very singular and extraordinary picture which it gives of Abyssinian manners, startled the belief of some; but these manners, though strange in the sight of an European, are little more than might be expected in such a barbarous country; and had an enlightened philosopher visited Scotland in the times of our earliest monarchs, he might perhaps have witnessed and related scenes, different indeed from what Mr Bruce saw in Abyssinia, but which to us would have seemed equally strange.

A more serious objection to the truth of Mr Bruce's narrative was started by an anonymous, but able, critic *, in an Edinburgh newspaper, soon after the publication, from the account of two astronomical phenomena, which *could not possibly have happened*, as Mr Bruce asserts. The first of these is the appearance of the new moon at Fushout, during Mr Bruce's stay in that place, which he mentions to have been from 25th December 1768 to the 7th of January 1769; and on a particular day in that interval asserts, that the new moon was seen by a fakir, and was found by the ephemerides to be three days old; whereas it is certain that the moon changed on the 8th of January 1769. The other phenomenon appears equally impossible. At Teawa Mr Bruce says he terrified the Shekh by foretelling that an eclipse of the moon was to take place at four afternoon of the 17th of April 1772; that accordingly, soon after that hour, he saw the eclipse was begun; and when the shadow was half over, told the Shekh that in a little time the moon would be totally darkened. Now, by calculation, it is certain that at Teawa this eclipse must have begun at 36 minutes past four, and the moon

have been totally covered at 33 minutes past five; while the sun set there a few minutes past six, before which time the moon, then in opposition, could not have risen: so that as the moon rose totally eclipsed, Mr Bruce could not see the shadow half over the disk, nor point it out to the Shekh. To these objections, which appear unfurmountable, Mr Bruce made no reply, though in conversation he said he would do it in the second edition of his book.

These are mistakes which can hardly be accounted for by attributing them to the inaccuracy of his notes, or indeed to any cause which we are inclined to name; and perhaps he has fallen into a mistake of the same kind in his account of the enormous main-sail yard of the *canja*, in which he failed up the river Nile. To every man who has but dipped into the science of mechanics, it is known that a beam of wood 200 feet in length, must be of proportional thickness, or it would fall in pieces by its own weight. This thickness must be greatly increased, to enable it to bear the strain occasioned by a prodigious sail filled with wind; and those only who have been at the Nile, and have seen the *canjas*, can say, whether these vessels, or indeed any vessels which can be employed on that river, would not be overset by yards,

—————To equal which, the tallest pine
Hewn on Norwegian hills, to be the mast
Of some great admiral, were but a wand.

The language of the work is in general harsh and unpolished, though sometimes animated. Too great a display of vanity runs through the whole, and the apparent facility with which the traveller gained the most familiar access to the courts, and even to the harems of the sovereigns of the countries through which he passed, is apt to create in readers some doubts of the accuracy of the narration. Yet there appears upon the whole such an air of manly veracity, and circumstances are mentioned with a minuteness so unlike deceit, that these doubts are overcome by the general impression of truth, which the whole detail irresistibly fastens upon the mind. The character of Ras Michael has often struck us, as containing very strong internal evidence of its having been taken from nature; for it is such a character, at once extraordinary and consistent, as neither Mr Bruce, nor perhaps any writer since Shakespeare, had genius to feign.

The first impression of the book being almost disposed of, Mr Bruce had stipulated with an eminent bookseller in London for a second edition to be published, we think in octavo; and he was busy in preparing that edition for the press when death removed him from this transitory stage. On the 26th of April 1794 he entertained some company at Kinnaird-house with his usual hospitality and elegance. About eight o'clock in the evening, when his guests were ready to depart, he was handing one of the ladies down stairs, when, having reached the seventh or eighth step from the bottom, his foot slipped, and he fell down headlong. He was taken up speechless; his face, particularly the forehead and temples, being severely cut and bruised, and the bones of his hands broken. He continued in a state of apparent insensibility for eight or nine hours, and expired on Sunday the 27th, in the 64th year of his age.

Mr Bruce's second wife, whom he married on the

* Supposed to be Dr Rotheram, professor of natural philosophy in the university of St Andrew's.

Bruce.

20th May 1776, was Mary, eldest daughter of Thomas Dundas, Esq; of Carron-hall, by Lady Janet Maitland, daughter of Charles sixth Earl of Lauderdale. By that lady, who, after a severe and lingering indisposition, died in 1784, he had three children, of whom one son and one daughter survive him.

Mr Bruce's person was large, his height exceeding six feet, his bulk being in proportion to his height; and at the period when he entered on his dangerous expedition, he was equally remarkable for strength and for agility. To those who never beheld him, the engraved medallion in the title pages of the first and third volumes of his Travels will convey some idea of his features. He excelled in all manly accomplishments, being trained to exercise and fatigue of every kind. He was a hardy, practised, and indefatigable swimmer; and his long residence among the Arabs had given him a more than ordinary facility in managing the horse. In the use of fire-arms he was so unerring, that in innumerable instances he never failed to hit the mark; and his dexterity in handling the spear and lance on horseback was also uncommonly great. He was master of most languages; and was so well skilled in oriental literature, that he revised the New Testament in the Ethiopic, Samaritan, Hebrew, and Syriac, making many useful notes and remarks on difficult passages. He had applied from early youth to mathematics, drawing, and astronomy, and had acquired some knowledge of physic and surgery. His memory was astonishingly retentive, and his mind vigorous. He was dexterous in negotiation, a master of public business, and animated with the warmest zeal for the glory of his king and country. Such, at least, is *his own* representation of his character; and though an impartial judge would probably make considerable abatement for the natural bias of a man drawing his own portrait, yet it cannot be denied, that in personal accomplishments Mr Bruce equalled, if not exceeded, most of his contemporaries.

Thus accomplished, he could not but be eminently fitted for an attempt so full of difficulty and danger as what he called the discovery of the sources of the Nile: no one who peruses his account of the expedition, can fail to pay an unfeigned tribute of admiration to his intrepidity, manliness, and uncommon dexterity, in extricating himself out of situations the most dangerous and alarming, in the course of his long and hazardous journey; not to mention his conduct during his residence in Abyssinia, his behaviour at Mafuah, Teawa, and Sennaar, evinces the uncommon vigour of his mind: but it was chiefly during his passage through the Nubian desert, that his fortitude, courage, and prudence, appeared to the greatest advantage. Of his learning and sagacity, his delineation of the course of Solomon's fleet from Tarshish to Ophir, his account of the cause of the inundations of the Nile, and his comprehensive view of the Abyssinian history, afford ample proofs. It must indeed be confessed, that in his account of the inundations of the Nile, as well as in his delineation of the course of Solomon's fleet, he has not the merit of originality; but on both these occasions he has stated the hypothesis which he maintains with greater clearness, and supported it with more plausible arguments, than any other author whose writings have fallen into our hands; and it was surely to his honour, that as soon as he learned that his hypothesis respecting Ophir and

Tarshish had been controverted by Dr Doig of Stirling, he earnestly courted the acquaintance of that eminent scholar.

After his return to his own country, he resided mostly at Kiunaird; and till he became corpulent, spent much of his time in the various sports of the field, in which he engaged with great ardour. Though studious in youth, and at all times a stranger to intemperance and dissipation, he read but little in his later years; and seemed to find his chief pleasure in conversation, especially the conversation of well-informed ladies. In his friendships he sometimes appeared to be capricious, attaching himself to men in whose heads and hearts no other person could perceive a charm for a mind like his. Though in his own dealings he was always just and honourable, he was too ready to apprehend unfairness in others, and to express such apprehensions with undue warmth. To strangers he was often arrogant, and sometimes insolent; but in his own family he was an affectionate husband, a kind father, an agreeable entertainer, and to his servants a master perhaps too indulgent. In conversation, as well as in his writings, he embraced every opportunity of expressing a deep and lively sense of the care of a superintending Providence, without which he was convinced that there could be no safety in human strength or human foresight. His belief of the Christian religion rested on the surest grounds; and such was his veneration for the sacred writings, that for some years before his death they seemed to occupy all the time which he gave to study. He read no sermons, however elegant; and dissuaded others from such reading. "Read the Bible (said he), and you will soon perceive the emptiness of the most applauded sermons."

BUCK-WHEAT, a species of POLYGANUM (see that article *Encycl.*), was first introduced into Europe about the end of the 15th or the beginning of the 16th century. According to some botanists, who lived at that period, its native country is the northern parts of Asia, whence it was brought to Germany and France, where, about the year 1587, it was the common food of the poor.

A new species of this grain, or, to speak perhaps more properly, a variety of this species, has been for some time known under the name of *Siberian buck-wheat*, which appears to have considerable advantages over the former. It was sent from Tartary to St Peterburgh by the German botanists, who travelled thro' that country in the beginning of the present century; and it has thence been dispersed over all Europe. Linnæus received the first seeds of it in 1737 from Garber the botanist, and described the plant in his *Hortus Cliffertionus*. After this it was mentioned by Ammann in 1739: but it must have been earlier known in Germany; for in 1733 it was growing in the garden of Dr Ehrhart at Memmingen. In Siberia this plant sows itself for four or five years by the grains that drop; but at the end of that period the land becomes so full of tares that it is choked, and must be sown afresh. Even in the economical gardens of Germany, it is propagated in the same manner; and in that country it is in some places found growing wild, though it is nowhere cultivated in the neighbourhood. It is not, however, indigenous, otherwise Ehrhart might have raised it from German seed, which it seems he could not find in 1733.

See

Bruce,
Buck-
wheat,

Bulam. See much curious information concerning this plant in Professor Beckmann's *History of Inventions and Discoveries*.

BULAM, or BULAMA, as it is more usually called, forms part of the Archipelago, or cluster of islands, lying on the western or windward coast of Africa, and known by the name of the *Bissaos* or *Bissagos*, which are supposed to have been celebrated by the ancients under the appellation of the *Hesperides*. It is situated at the mouth of the Rio Grande, in 11° N. Lat. and 15° W. Long. from the meridian of London; and is between seventeen and eighteen leagues long, and from four to five broad.

This island has become an interesting object to the inhabitants of Great Britain, in consequence of its having been purchased in the year 1792 by a society instituted for the same humane purposes with those which gave rise to the Sierra-Leona company (see *SIERRA-LEONA*, Encycl.) The Bulam association was formed towards the latter end of the year 1791; and they were induced to pitch upon that island as the most eligible tract for their intended colony, in consequence of the flattering description given of its climate, soil, and harbours, by M. Brue, formerly director-general of the French African companies.

The gentlemen originally appointed as trustees for managing the concerns of the association at home were, *Paul Le Mesurier*, M. P.; *James Kirkpatrick*, Esq; *George Hartwell*, Esq; *Moses Ximenes*, Esq; *Sir John Riggs Miller*, Bart. and *David Scott*, Esq. M. P.; and for establishing the colony, and conducting the affairs of the society abroad, the following gentlemen were nominated, viz. *Messrs H. H. Dalrymple*, *John Young*, *Sir William Halton*, Bart. *John King*, *Philip Beaver*, *Peter Clutterbuck*, *Nicholas Bayly*, *Francis Brodie*, *Charles Drake*, *John Paiba*, *Richard Hancorne*, *Robert Dobbins*, and *Isaac Ximenes*.

A sum of L. 9000 being quickly subscribed for the establishment of the intended colony, this committee sailed from Spithead in three ships on the 11th of April 1792; and landing in due time at Bulama, they purchased that island from the kings of Canabac, who claimed it as their property. They purchased likewise from the kings of Ghinala the neighbouring island Arcas, and the adjacent land on the continent; and these several purchases being taken possession of in the usual form, a body of settlers, consisting of 49 men, 13 women, and 25 children, were left at Bulama under the superintendance of Mr Beaver, with a temporary supply of provisions, stores, plantation-tools, and merchandise, for trading with the neighbouring natives. It is from the dispatches of these settlers, after having lived some time in Bulama, that the following account of the island was drawn up by Mr Johansen.

"The climate, on the whole, may be deemed salubrious, and will become more so in proportion to the increase of cultivation. The mornings and evenings are temperate and pleasant; the middle of the day is hot, but the fine sea breeze which then sets in tends greatly to cool and refresh the air. The heat of the sun is not either so excessive or intolerable as has been generally supposed: indeed nature has most admirably adapted our mechanical and physical qualities to the exigencies of different regions; and man, who is the inhabitant of every climate, may, in some measure, render himself in-

digenous to every soil. Here the only danger arises from too sudden an exposure to the operation of the vertical rays of the sun, or an excess of labour; both of which the first settlers ought most studiously to avoid.

"It appears from Mr Beaver's observations at noon, between the 20th of July 1792, and the 28th of April 1793, that the thermometer, when lowest, was at 74; the medium heat 85; and that it never exceeded 96, except at one time when it rose to 100, during a calm that occurred in the interval between the north-east breeze in the morning and the south-west in the evening of the 19th of February 1793. The difference between the heat of noon and that of the morning and evening is from 20 to 30 degrees. On the 23d of October 1792, hail of the size of a pin's head fell during two minutes, although not a cloud was to be seen during this phenomenon. The mercury in the thermometer then stood at 85; the wind was at north-east in the morning and south-west in the evening.

"Immediately after sun-set a dew constantly begins to fall, which induces some to light a fire in their houses; they at the same time put on warmer clothing. There is little or no twilight; and night and day are nearly equal: the earth has therefore time to cool during twelve hours absence of the sun.

"None of those terrible and destructive hurricanes so frequently experienced in the West Indies are to be met with here. The *tornadoes*, which arise chiefly from the eastern point of the compass, are but of short duration, seldom lasting above an hour, and may be readily foreseen some time previously to their commencement. They occur at the beginning and close of the wet season, and are highly beneficial, as they purify the air, and dispel the noxious vapours with which it would otherwise abound.

"The rains set in about the latter end of May or the beginning of June, and discontinue in October or November. They do not fall every day, for there is often a considerable interval of clear weather, during which the atmosphere is beautifully serene; the showers in the first and last month occur but seldom, and are far from being violent; while, on the other hand, they sometimes resemble torrents, more especially towards the middle of the season. During the whole of this period, Europeans should, if possible, confine themselves to their habitations, as the rains prove injurious to health, more especially if those exposed to them neglect to wipe their bodies dry, and to change their clothes immediately on their return home. It is deemed prudent also not to dig the earth until the expiration of a month after the return of fair weather, as this is considered to be unhealthy.

"During the continuance of the dry season, a dew falls during the night, in sufficient quantity to answer all the purposes of vegetation.

"Every stranger is generally here, as well as in the West Indies, subject to a fever or *seasoning* on his arrival. This is not infectious; it proceeds perhaps from an increased perspiration and a sudden extension of the pores of the human body, in consequence of the heat, by which means it is rendered more liable to imbibe the abundant exhalations that arise from the animal, vegetable, and mineral kingdoms; but even this, slight as it is, might doubtless be avoided by means of a proper regimen, and a short seclusion from the full action of the

Bulam. the open air, more especially at noon, and during the evening, until the climate has been rendered familiar.

“Bulama is admirably adapted for all the purposes of an extensive commerce, being not only happily situated at the mouth of the Rio Grande, but in the vicinity of several other navigable rivers; so that a trade with the internal parts of Africa is thereby greatly facilitated. The landing is remarkably easy and safe, there being no surge; the ebb and flow is regular, and there is an increase of 16 feet of water at spring tide. The bay opposite the Great Bulama is adorned with a number of islands, covered with trees, and forms a most excellent harbour, sufficiently capacious to contain the whole navy of Great Britain, which might ride there in safety. The settlement in general is well supplied with water. A number of springs have been lately discovered in different places; and besides a draw-well in the fort, which was erected for the defence of the colony, there is a small stream, which runs into Elewis Bay, near the new settlement called Hesper Elewis: this is admirably situated for the supply of shipping.

“The island is beautifully surrounded, and interspersed with woods: lofty fruit and forest trees, mostly free from underwood and brambles, form a verdant belt, in some places two or three miles broad, which entirely encircles it, in such a manner as to represent a plantation artificially formed around a park. Within this the fields are regularly divided by trees, so as to resemble the hedge-rows in England. The beach has in some places the appearance of gravel walks; it is fringed with mangrove trees, which forming a line with the high-water mark, dip their branches into the sea, and thus afford nourishment to the oysters that often adhere to their extremities.

“Several parts of Bulama have been occasionally cultivated by the neighbouring blacks, though they did not constantly reside on it.

“The land in general rises gradually towards the middle of the island, where the highest spot is from 60 to 100 feet above the level of the sea. The small hill on which the fort is situated is nearly of the same altitude.

“The soil is abundantly rich and deep; stones do not here impede the labours of the farmer; and indeed none have hitherto been discovered, but a small fort, resembling pieces of ore, which are to be met with on the shore. There are many *savannahs* or natural meadows, so extensive that the eye can scarcely descry their boundaries. These are admirably adapted for the rearing of stock and feeding of cattle of every kind.

“Cotton, indigo, rice, and coffee, grow spontaneously on this coast; the sugar-cane is indigenous to many parts of Africa, and might be cultivated here by the labour of freemen, in equal perfection, and to much greater advantage, than in the exhausted islands of the West Indies. All kinds of tropical productions, such as pine-apples, limes, oranges, grapes, plums, cassada, guava, Indian wheat, the papaw, water-melon, muskmelon, the pumpkin, tamarind, banana, and numbers of other delicious fruits, also flourish here. The adjoining territories produce many valuable sorts of spices,

Bulam. gums, and materials for dyeing: all of which it is but fair to suppose, might be readily cultivated in a kindred climate and a congenial soil.

“The neighbouring seas abound with a variety of fish, highly agreeable to the palate. The lion, tyger, jackall, &c. are natives of the continent; but in Bulama no animals have been discovered, the wolf, some buffaloes, a few elephants, and a species of the deer, excepted.

“The woods abound with doves, guinea-fowls, and a variety of birds, celebrated for the beauty of their plumage.

“The natives of this part of Africa, like all savages, are entirely under the dominion of their passions: hence the violence of their attachment to their friends, and the excess of their resentment against their enemies. Their notions of property are very obscure and confused: they have no idea of any right arising from occupancy or improvement. What they want, they either receive or take wherever they may happen to meet with it, and they permit others to do the same. They have been taught by experience that the Europeans will not agree to this: against them therefore they employ every artifice that it is in the power of cunning to suggest.

“The colonists need not fear any attack on the part of the negroes, provided their own conduct be just and peaceable: for Mr Beaver, who was indeed admirably calculated by nature and habit for the station he occupied, could ensure both safety and respect when the settlers under him were reduced to four white men, although the neighbouring nations knew that he was in possession of commodities, for the acquisition of which many of them had become day-labourers. He often kept from twenty to forty gromittos, or black cultivators in pay, at that very period, at about four or five bars (A) each per month. These are easy to be procured, to almost any number that can possibly be wanted.

“Until a sufficient quantity of stock and provisions can be raised in the company's settlements, the adjacent islands will furnish abundance of cattle, hogs, fowls, &c. at a very cheap rate. A horse may be purchased at Goree for 1l. 10s. a bullock may be had from 12s. to 18s. sterling: provisions of all kinds are equally reasonable. Honey is also to be procured in great plenty, and bees-wax may be rendered an advantageous object of commercial speculation.

“In short, the acquisition of Bulama, Arcas, and the adjacent territories, presents the fairest opportunity of furnishing Europe with many valuable articles that have hitherto been brought from more remote countries, with much greater hazard, and at an increased expence. The intercourse with England is easy, safe, and expeditious; for the voyage may be performed in the space of three or four weeks: and by the terms of the first subscription, a settler on Bulama might purchase 500 acres of land for L. 30 Sterling; by the terms of the second, which we suppose are the terms at present, he might purchase on the islands of Bulama and Arcas, or on that part of the adjacent coast which was ceded to the society by the kings of Ghinala, 200 acres for L. 50 sterling.

“The

(A) A bar is about the value of three shillings and sixpence.

Bunting.

"The colonization of Africa opens a noble and extensive field to nations and to individuals. To people those fertile territories, despoiled of their inhabitants by the slave-trade; to rear the productions of the climes between the tropics, by the assistance of free men; to give ample scope to the industry and exertions of those who may be inclined to remove from Great Britain; and to extend the commerce and the manufactures of our native country—these are subjects which have excited the attention of the Bulama association, and now claim the assistance of the ingenious, the support of the rich, and the concurrence and good wishes of all."

BUNTING, is a bird which has been described under its generic name *EMBERIZA* (*Encycl.*); but there is one species, the *orange shouldered bunting* of Latham, of which M. Vaillant relates some particulars certainly not unworthy of notice in this place.

"The female of this beautiful bird (says he) has the simple colours of the sky-lark, and a short horizontal tail, like that of almost all other birds: the male, on the contrary, is wholly black except at the shoulder of the wing, where there is a large red patch; and his tail is long, ample, and vertical, like that of the common cock. But this brilliant plumage and fine vertical tail subsist only during the season of love, which continues six months. This period over, he lays aside his splendid habiliments, and assumes the more modest dress of his mate. The most extraordinary circumstance is, that the vertical tail also changes to a horizontal one, and the male so exactly resembles the female, that it is not possible to distinguish them from each other.

"The female has her turn. When she reaches a certain age, and has lost the faculty of propagating the species, she clothes herself for the remainder of her days in the garb which the male had temporarily assumed; her tail, like his at that period, grows long, and, like his also, from horizontal becomes vertical.

"The birds of this species associate together, live in a sort of republic, and build their nests near to each other. The society usually consists of about fourscore females; but, whether by a particular law of nature, more females are produced than males, or for any other reason of which I am ignorant, there are never more than twelve or fifteen males to this number of females, who have them in common."

According to our author, this transmutation is by no means confined to this particular species of bunting. Many females of the feathered creation, when they grow so old as to cease laying eggs, assume the more splendid colours of the male, which they retain during the remainder of their lives. This fact is strikingly perceptible in those species in which the male and female very much differ in colour, as the golden pheasant of China, for instance. In some species, and those not a few, the male alone regularly changes his colour, and assumes once in a year the plumage of the female; so that at a certain period all the birds of that species appear females. "I have in my possession (says our author) specimens of more than fifty of those changing species, in all their transitions from one hue to another; and the change is sometimes so great, that a person would suppose himself to see individuals totally different. A closet-naturalist, for instance, shewed me four birds as so many different species, and even as not belonging to the same genus, with which I was well ac-

quainted, and which I knew to be the same bird, only of different ages."

Such changes as these, could they be proved to take place occasionally among domestic fowls, would in some measure account for strange stories of cocks laying eggs, which we have heard related by persons whose general veracity was never questioned.

BURKE (Edmund), was born in the city of Dublin on the 1st of January 1730. His father was an attorney of considerable knowledge in his profession, and of extensive practice; and the family from which he sprung was ancient and honourable. He received the rudiments of his classical education under Abraham Shackleton, a Quaker, who kept a private school or academy, as it has been called, at Bellymore, near Carlow, and is said to have been a very skilful and successful teacher.

Under the tuition of this master, Burke devoted himself with great ardour, industry, and perseverance, to his studies; and manifested, even from his boyish days, a distinguished superiority over his contemporaries. He was the pride of his preceptor, who prognosticated every thing great from his genius, and who was, in return, treated by his illustrious pupil, for forty years, with respect and gratitude.

From school Burke was sent to Trinity-college, Dublin, where it was asserted by Goldsmith and others his contemporaries, that he displayed no particular eminence in the performance of his exercises. Like Swift, he despised the logic of the schools; and like him too, he devoted his time and his talents to more useful pursuits. Johnson, though proud of being an Oxonian, did not much employ himself in academical exercises; and Dryden and Milton, who studied at Cambridge, were neither of them ambitious of college distinctions. Let, not, however, the example of a Burke, a Johnson, a Dryden, or a Milton, seduce into by-paths the ordinary student; for though great genius either finds or makes its own way, common minds must be content to pursue the beaten track. Shakespeare, with very little learning, was the greatest dramatic poet that ever wrote; but how absurd would it be to infer from this fact, that every illiterate man may excel in dramatic poetry?

Whilst at college Burke applied himself with sufficient diligence to those branches of mathematical and physical science which are most subservient to the purposes of life; and though he neglected the syllogistic logic of Aristotle, he cultivated the method of induction pointed out by Bacon. Pneumatology, likewise, and ethics, occupied a considerable portion of his attention; and whilst attending to the acquisition of knowledge, he did not neglect the means of communicating it. He studied rhetoric and the art of composition, as well as logic, physics, history, and moral philosophy; and had at an early period of his life, says Dr Bisset, planned a confutation of the metaphysical theories of Berkeley and Hume.

For such a task as this, we do not think that nature intended him. Through the ever-active mind of Burke ideas seem to have flowed with too great rapidity to permit him to give that patient attention to minute distinctions, without which it is vain to attempt a confutation of the subtleties of Berkeley and Hume. The ablest antagonist of these two philosophers was remarkable for patient thinking, and even *apparent* slowness of apprehension;

Burke. apprehension; and we have not a doubt, but that if he had possessed the rapidity of thought which characterised Burke, his confutation of Hume and Berkeley would have been far from conclusive. It might have been equal to the *Essay on the Nature and Immutability of Truth*, but would not have been what we find it in *The Inquiry into the Human Mind on the Principles of Common Sense*, and in *The Essays on the Intellectual and Active Powers of Man*.

A task much better suited to Burke's talents than the writing of metaphysical disquisitions on the substratum of body, presented itself to him in the year 1749, and a task which was likewise more immediately useful. At that period one Lucas, a democratic apothecary, wrote a number of very daring papers against government, and acquired by them as great popularity at Dublin as Mr Wilkes afterwards obtained by his *North Briton* in London. Burke, though a boy, perceived, almost intuitively, the pernicious tendency of such levelling doctrines, and resolved to counteract it. He wrote several essays in the style of Lucas, imitating it so exactly as to deceive the public; pursuing his principles to consequences necessarily resulting from them, and shewing at the same time their absurdity and their danger. Thus was his first literary effort, like his last, calculated to guard his country against anarchical innovations.

Whilst employed in treasuring up knowledge, which at a future period was to command the admiration of listening senates, he did not neglect the means necessary to render himself agreeable in the varied intercourse of private life. To the learning of a scholar he added the manners of a gentleman. His company was sought among the gay and the fashionable, for his pleasing conversation and easy deportment; as much as among the learned, for the force and brilliancy of his genius, and the extent and depth of his knowledge. But though the object of very general regard in his native country, he had hardly any prospect of obtaining in it an independent settlement. He therefore applied, some time after the publication of his letters exposing the doctrines of Lucas, for the professorship of logic, which had then become vacant in the university of Glasgow: but whether that application was made too late, or that the university was unwilling to receive a stranger, certain it is that the vacant chair was filled by another, and that Burke was disappointed of an office in which he was eminently qualified to excel. For many years very little attention has been paid in the universities of Scotland, perhaps even too little, to the Aristotelian logic; and the professors, instead of employing their time in the analysing of syllogisms, deliver lectures on rhetoric and the principles of composition—lectures which no man was more capable of giving than the unsuccessful candidate for the professorship in Glasgow.

Disappointment of early views has frequently been the means of future advancement. Had Johnson become master of the Staffordshire school, talents might have been consumed in the tuition of boys which Providence formed for the instruction of men; and had Burke obtained the professorship of logic in Glasgow, he would have been the most eloquent lecturer in that university, instead of the most brilliant speaker in the British senate: but whether his talents might not have been as usefully employed in the university as in the se-

nate, may perhaps be a question, though there can be no question whether they would have invested himself with an equal blaze of splendour.

Disappointed in Glasgow, he went to London, where he immediately entered himself of the Temple; and as there is reason to believe that he was in straitened circumstances, he submitted to the drudgery of regularly writing for daily, weekly, and monthly publications, essays on general literature and particular politics. The profits arising from such writings were at first small; but they were so necessary to their author, that the intense application which they required gradually impaired his health, till at last a dangerous illness ensued, when he resorted for medical advice to Dr Nugent, a physician whose skill in his profession was equalled only by the benevolence of his heart. The Doctor, considering that the noise, and various disturbances incidental to chambers, must retard the recovery of his patient, furnished him with apartments in his own house, where the attention of every member of the family contributed more than medicines to the restoration of his health. It was during this period that the amiable manners of Miss Nugent, the Doctor's daughter, made a deep impression on the heart of Burke; and as she could not be insensible to such merit as his, they felt for each other a mutual attachment, and were married soon after his recovery.

Hitherto his mental powers and acquirements were known in their full extent only to his friends and more intimate companions; but they were now made public in his first acknowledged work, intitled, *A Vindication of Natural Society*. The object of this performance was to expose the dangerous tendency of Lord Bolingbroke's philosophy. By the admirers of that nobleman, his principles were deemed inimical only to revealed religion and national churches, which they would have been glad to see overturned, provided our civil establishment had been preserved; and to the civil establishment they perceived no danger in the writings of the author of *The Patriot King*. Mr Burke thought very differently; and endeavoured to convince them, that if his Lordship's philosophy should become general, it would ultimately destroy their rank, their consequence, and their property, and involve the church and state in one common ruin. In his ironical attack upon artificial society, he makes use of the same common place mode of unfair reasoning which his noble antagonist had employed against religion and religious establishments. He argues, from the incidental abuses of political society, that political society must itself be evil; he goes over every form of civil polity, pointing out its defects in the most forcible language; and, in perfect imitation of the sceptical philosophy, he pulls them all down, one after another, without proposing any thing in their stead. So complete is the irony, that to many not acquainted with such disquisitions, he would appear to be seriously inveighing against civil government; and we have actually heard some of the advocates for modern innovation mention this work as a proof how different Mr Burke's opinions in politics once were from what they appear to have been when he wrote his *Reflections on the French Revolution*.

The truth, however, is, that there is no inconsistency between *The Vindication of Natural Society* and the latest publications of its illustrious author. At the pe-

riod when that work was published, infidelity had infected only the higher orders of men, and such of the lower as had got the rudiments of a liberal education. Of these we believe a single individual was not then to be found, who supposed that society could subsist both without government and without religion; and therefore while they laboured to overturn the church, and to prove that Christianity itself is an imposture, they all pretended to be zealously attached to our civil government as established in king, lords, and commons. Except the clergy of the established church, there was no order of men whom they indiscriminately reviled. Hence it was that not Burke only, but Warburton, and almost every other opponent of Lord Bolingbroke, began their defences of revelation, by shewing the indissoluble connection between our civil and ecclesiastical establishments; and all the difference was, that he did, through the medium of the most refined irony, the very same thing which they had done by serious reasoning.

Soon after his *Vindication of Natural Society*, Burke published *A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful*; a work which soon made its author universally known and admired, and which has been studied by every English reader of taste. It is therefore needless for us to hazard any opinion either of its general merit or its particular defects. In one of the literary journals of that day, Mr Murphy urged objections against some of its fundamental principles, which, in our opinion, it would be very difficult to answer; whilst Johnson, who was certainly a severe judge, considered it as a model of philosophical criticism. "We have (said he) an example of true criticism in Burke's Essay on the Sublime and Beautiful. There is no great merit in shewing how many plays have ghosts in them, or how this ghost is better than that; you must shew how terror is impressed on the mind."

In consequence of this manifestation of Burke's intellectual powers, his acquaintance was courted by men of distinguished talents, and, among others, by Johnson and Sir Joshua Reynolds. The literary club which has been mentioned (*Encycl.*) in the life of JOHNSON, was instituted for their entertainment and instruction, and consisted at first of Johnson, Burke, Reynolds, Goldsmith, Dr Nugent, Mr Topham, Beauclerk, Sir John Hawkins, Mr Chamier, and Mr Bennet Langton, who were all men of letters and general information, though far above the rest stood Burke and Johnson. Of Burke indeed Johnson declared, upon all occasions, that he was the greatest man living; whilst Burke, on a very solemn occasion, said of Johnson, "He has made a chasm, which not only nothing can fill up, but which nothing has a tendency to fill up. Johnson is dead. Let us go to the next best—There is nobody—No man can be said to put you in mind of Johnson." Nor was the opinion which these two illustrious men held of each other's powers peculiar to themselves alone: all the members of the club observed, that in colloquial talents they were nearly matched, and that Johnson never discoursed with such animation and energy as when his powers were called forth by those of Burke.

Some years before the institution of this club, Burke, who had devoted much of his time to the study of history and politics, proposed to Mr Doddsley, an eminent bookseller, a plan of an ANNUAL REGISTER of the

vil, political, and literary transactions of the times; and the proposal being acceded to, the work was begun and carried on for many years, either by Burke himself, or under his immediate inspection. It bears indeed internal marks of his genius, his learning, and his candour, being by much the most elegant and impartial periodical history which has perhaps appeared in any age or nation. Even when the heat of opposition made him, in his speeches, sometimes misrepresent the conduct of administration, the Annual Register, under his management, continued to render justice to all parties.

He still continued to write occasionally political essays for other publications than the Annual Register; and some of these essays in the *Public Advertiser* having attracted the notice of the Marquis of Rockingham, that nobleman sought the acquaintance of their author. It was in the year 1765 that the first interview took place between them; and the Marquis, who was then at the head of the treasury, offering to make Burke his own secretary, the offer was readily accepted. On this occasion he gave a remarkable proof of disinterestedness and delicate integrity. Through the influence of Mr Hamilton, known by the appellation of *Single Speech* Hamilton, and long suspected to be the author of *Junius's Letters*, he had some time before obtained a pension of L. 300 a-year on the Irish establishment; but this pension he now thought it incumbent upon him to resign, because he had connected himself with a party opposite in many things to the party whose measures were supported by his friend.

During the Rockingham administration he was chosen member of Parliament for the borough of Wendover in the county of Bucks; and he prepared himself for becoming a public speaker, by studying, still more closely than he had yet done, history, poetry, and philosophy; and by storing his mind with facts, images, reasonings, and sentiments. He paid great attention likewise to parliamentary usage; and was at much pains to become acquainted with old records, patents, and precedents, so as to render himself complete master of the business of office. That he might communicate without embarrassment the knowledge which he had thus laboriously acquired, he frequented, with many other men of eminence, the Robin Hood Society, where he practised the replies and contentions of eloquence; and to acquire a graceful action, with the proper management of his voice, he was a very diligent observer of Garrick in Drury-Lane theatre. He procured his seat in 1765, and in the ensuing session delivered his maiden speech; which was such a display of eloquence as excited the admiration of the House, and drew very high praise from its most distinguished member Mr Pitt, afterwards Earl of Chatham.

The principal objects which engaged the attention of the Rockingham administration were the ferment in America, which was then in a state little short of rebellion, on account of the famous stamp-act. Parliament was divided in opinion respecting that measure. Whilst Mr Grenville and his party (under whose auspices the stamp-act had passed into a law) were for enforcing obedience to it by coercive measures, Mr Pitt and his followers denied that the parliament of Great Britain had a right to tax the Americans; and the marquis of Rockingham, who was hardly able to carry any measure in opposition to both these parties, had to con-

Burke. sider, on this occasion, whose sentiments he would adopt. By the advice, it is said, of Mr Burke, he chose a middle course between the two opposite extremes. To gratify the Americans, he repealed the stamp-act; and to vindicate the honour of Britain, he got a law passed declaratory of her right to legislate for America in taxation as in every other case.

This measure, whoever was its author, was certainly not the offspring either of wisdom or vigour. If the mother-country had a right to legislate in all cases for America, obedience to the stamp-act should certainly have been enforced; and the ministry which relinquished an acknowledged right, to gratify the factious disposition of distant colonies, was obviously unfit to guide the helm of a great empire. Lord Rockingham and his friends were accordingly dismissed from office; and a new administration was formed under the auspices of Mr Pitt, now created earl of Chatham.

Burke, in the mean time, wrote in defence of the party with which he was connected; and assumed great credit to it for composing the distractions of the British empire by the repeal of the American stamp-act, whilst the constitutional superiority of Great Britain was preferred by the act for securing the dependence of the colonies. After defending his friends, he proceeds to attack those who had succeeded them in office. Of Lord Chatham he says—"He has once more deigned to take the reins of government into his own hand, and will, no doubt, drive with his wonted speed, and raise a deal of dust around him. His horses are all matched to his mind; but as some of them are young and skittish, it is said he has adopted the new contrivance lately exhibited by Sir Francis Delaval on Westminster bridge: whenever they begin to snort and toss up their heads, he touches the spring, throws them loose, and away they go, leaving his lordship safe and snug, and as much at his ease as if he sat on a wool-pack."

The letter, of which this is an extract, was printed in the Public Advertiser; and is said to have contributed, in no small degree, to lessen the popularity of the illustrious statesman against whom it was written. The ministry, indeed, which he had formed, consisted of very heterogeneous materials, and was not heartily approved of by the nation. It therefore soon fell in pieces by its own discord, and Lord Chatham retired in disgust.

The parliament being dissolved in 1768, Burke was re-elected for Wendover, and took his seat, when the house met, in November. The duke of Grafton was now prime minister, and was opposed by two powerful parties in parliament; that of the marquis of Rockingham, and that of which Mr Grenville was considered as the leader. These two parties, however, differed widely between themselves. Mr Grenville had published a pamphlet, intitled, *The Present State of the Nation*; in which he very ably vindicated his own measures, and of course condemned the measures of those who had succeeded him; and Burke replied to him, with greater eloquence, but perhaps with less of argument, in a tract, intitled, *Observations on the Present State of the Nation*, in which he makes a very high panegyric on his own patron, and the connections of the party, and animadverts with cutting severity on their successors in office.

Burke. About this period commenced the national frenzy which was excited by the expulsion of Wilkes from the house of commons, for having printed and published a seditious libel, and three obscene and impious libels. In the controversy to which this transaction gave rise, Burke and Johnson took opposite sides. Johnson, in his *False Alarm*, contends, with great ability, that the expulsion of a member from the house of commons for the commission of a crime, amounts to a disqualification of that member from sitting in the parliament from which he is expelled; whilst Burke, though he disapproved of the conduct of Wilkes as much as his friend, laboured to prove, that nothing but an act of the legislature can disqualify any person from sitting in parliament who is regularly chosen, by a majority of electors, to fill a vacant seat. It does not appear that this difference of opinion produced the smallest abatement of mutual regard between him and Johnson. They both attended the weekly club, and were as much pleased with each other as formerly.

The proceedings of the Grafton administration, respecting Wilkes and other subjects, gave rise to the celebrated *Letters of Junius*. That those compositions were, in clearness, neatness, and precision of style, infinitely superior to perhaps every other series of newspaper invectives, has never been controverted; and that they display a vast extent of historical and political information, is known to all who are not themselves strangers to the history of this kingdom. Unclaimed by any author, and superior to the productions of most authors, they have been given to Burke, to his brother Richard, a man likewise of very bright talents, to Mr Hamilton, and to Lord George Germaine. We should hardly hesitate to adopt the opinion of those who ascribe them to Burke, had he not disavowed them to his friend Johnson. "I should have believed Burke to be Junius (said Johnson), because I know no man but Burke who is capable of writing these letters; but Burke spontaneously denied it to me. The case would have been different had I asked him if he was the author. A man may think he has a right to deny when so questioned as to an anonymous publication." The difference between the style of these letters and that of Burke's acknowledged writings, would have had no weight with us; because such was his command of language, that he could assume, and occasionally did assume, any style which he chose to imitate. He had already so closely imitated the very different styles of Lucas and Bolingbroke as to deceive the public; and what was to hinder him from imitating the style of Lord George Germaine, which certainly has a strong resemblance to that of Junius? We think, however, with Johnson, that his *spontaneous disavowal* of these letters ought to be held as sufficient proof that he was not their author.

Burke had now gotten a very pleasant villa near Beaconsfield in Buckinghamshire; and being one of the freeholders of the county, he drew up a petition to the king, complaining of the conduct of the house of commons respecting the Middlesex election, and praying for a dissolution of the parliament. The petition, though explicit and firm, was temperate and decorous, and as unlike to one on the same subject from the livery of London, as the principles of a moderate Whig are to those of a turbulent democrat.

Burke.
 About this period he stated very clearly his own political principles in a pamphlet intitled, "Thoughts on the Causes of the Present Discontents;" and his plan for removing these discontents had not a grain of democracy in its composition. He proposed to place the government in the hands of an open aristocracy of talents, virtue, property, and rank, combined together on avowed principles, and supported by the approbation and confidence of the people; and the aristocracy which he thought fittest for this great trust, was a combination of those Whig families which had most powerfully supported the revolution and consequent establishments. He expressed, in strong terms, his disapprobation of any change in the constitution and duration of parliament; and declared himself as averse from an administration which should have no other support than popular favour, as from one brought forward merely by the influence of the court.

In this plan there is not that wisdom or liberality which might have been expected from a man of Burke's cultivated mind and extensive reading. The Whigs, when in power, had been as venal as the Tories; and the imprisonment of Lord Oxford, the banishment of Atterbury bishop of Rochester, and the resolution of the house of commons to sit for seven years, when it had been chosen by its constituents for no more than three, were certainly greater violations of the constitution than the disqualification of Wilkes, or any other measure that had been carried by the court during the administrations of Grenville and the duke of Grafton. Burke shewed himself in this publication to be indeed no republican; but every sentence of it breathed the spirit of party.

Lord North was now prime minister; and in order to tranquillize America, he proposed, in the beginning of his administration, to repeal the obnoxious laws of his predecessors in office, and to reserve the duty on tea merely to maintain the authority of parliament. The consequences of this conduct we have detailed elsewhere (see BRITAIN, *Encycl.*); and they are too well known to all our readers. The part which Burke acted during his administration will not, in our opinion, admit of any plausible defence. It was not indeed the part of a democrat, but of a man determined to oppose every measure of those in power. In the beginning of the contest, he certainly displayed more wisdom and patriotism than the minister; for, without entering directly into the question, Whether the mother-country had or had not a right to tax the colonies? he contented himself with warning the house against dangerous innovations. "The Americans (said he) have been very serviceable to Britain under the old system: do not, therefore, let us enter rashly upon new measures. Our commercial interests have been hitherto greatly promoted by our friendly intercourse with the colonies; do not let us endanger possession for contingency; do not let us substitute untried theories for a system experimentally ascertained to be useful."

This was undoubtedly found reasoning, and every way becoming a lover of his country: but his continued opposition to government, after all Europe had leagued against Great Britain, was a conduct which will admit of no vindication, and for which the only possible apology must be found in that ardour of temper which made his friend Hamilton say, on another occasion,

Burke.
 "Whatever opinion Burke, from any motive, supports, so ductile is his imagination, that he soon conceives it to be right." In his most violent opposition, however, though his expressions were often extravagant and indecent, he never for a moment gave his support to the metaphysical doctrine of the *imprescriptible rights of man*, or to the actual innovations which some meant to introduce on the basis of that doctrine. His upright mind was indeed sufficiently guarded against these novelties by what he had observed in France during the year 1772. Whilst he remained in that country, his literary and political eminence made him courted by all the anti-monarchical and infidel philosophers of the time; and in the religious scepticism and political theories of Voltaire, Helvetius, Rousseau, and D'Alembert, he saw, even at that period, the probable overthrow of religion and government. His sentiments on this subject he took occasion, immediately on his return, to communicate to the house of commons; and to point out the conspiracy of atheism to the watchful policy of every government. He professed that he was not over-fond of calling in the aid of the secular arm to suppress doctrines and opinions; but he recommended a grand alliance among all believers against those ministers of rebellious darkness, who were endeavouring to shake all the works of God established in beauty and in order.

The American war proving unsuccessful, though Great Britain never made a more glorious stand, Lord North and his friends retired from office; and, in February 1782, a new ministry was formed, at the head of which was placed the marquis of Rockingham; Lord Shelburne and Mr Fox were the secretaries of state; and Mr Burke, who was appointed pay-master to the forces, exulted, rather childishly, in the house of commons, on the happiness which was to accrue, both to the king and to the people, from the able and upright conduct of the new ministers. The time in which the greater part of them continued in office was too short to permit them to do either much good or much evil.

On the 1st of July the marquis of Rockingham died; and the earl of Shelburne being placed at the head of the treasury, Fox and Burke resigned in disgust, and, to the astonishment of the nation, formed the famous coalition with Lord North, whose measures they had so long, and so vehemently opposed. In the coalition of North and Burke there would have been nothing wonderful. In the intercourse of private life, these two statesmen had always met on terms of friendship and mutual regard; they had the same ideas of the excellence of the constitution, and the same aversion to innovation under the name of reform; even their studies and amusements were very similar, being both men of taste and classical learning; and though Burke opposed the taxation of America by the British parliament, his opposition proceeded rather from motives of prudence and expediency than from any settled conviction that the measure was unconstitutional. But the political enmity of Fox and North had proceeded, not only to personal abuse, but to professions of mutual abhorrence; and perhaps there was hardly an unprejudiced person in the kingdom who entertained not suspicions, that the unexpected union of such enemies was cemented by a principle less pure than patriotism.

Mr Pitt was now chancellor of the exchequer; and when he announced to the house of commons the peace

Burke.

which was concluded in January 1783, he found the terms on which it had been made severely condemned by North, Fox, Burke, and all their friends. The censure passed on it by Lord North and his followers was perfectly consistent with their former conduct, and with the opinions which they had uniformly maintained; but it was with no good grace that Fox and Burke, who had offered an unconditional peace to the Dutch, and so frequently proposed to recognize the independence of America, condemned the peace which had been concluded by Lord Shelburne. On this, as on many other occasions, they acted, not as enlightened politicians, but as the rancorous leaders of a party.

In consequence of a vote of censure passed by the commons, the ministers resigned their employments, and were succeeded by the duke of Portland, Lord North, Mr Fox, Mr Burke, and their friends. Burke had his former employment of paymaster to the forces; Lord North and Mr Fox were secretaries of state, and the duke of Portland was first lord of the treasury. To many persons this ministry had the appearance of greater strength than any that had governed the kingdom since the time of Sir Robert Walpole; but its duration was not longer than that of the preceding. On the 18th of November, Mr Fox introduced his famous India-bill, into the merits of which it is foreign from our purpose to enter: suffice it to say, that after being strongly supported by Burke, and ably opposed by Pitt and Dundas, it passed the house of commons by a very great majority; but was lost in the house of peers, and viewed by the king in such a light, that he determined on an entire change of administration.

Mr Pitt was now placed at the head of the treasury, where he has remained ever since (1800), notwithstanding the violent and powerful opposition which he met with at first from North and Fox and their coalesced friends: the voice of the nation has been on his side; and that voice will always drown the bellings of patriotism.

The principal events in which Burke signalized himself, since the year 1784, were the trial of Hastings, the deliberations of the house on the proposed regency during the lamented illness of the king, and the French revolution; and on each of these occasions he displayed talents which astonished the nation. He has, indeed, been severely blamed for the pertinacity with which he prosecuted Mr Hastings, and his conduct has been attributed to very unworthy motives; but of this there is neither proof nor probability. The temperament of his mind was such, that, into whatever measure he entered, he entered with a degree of ardour of which cooler heads can hardly form a conception. Burke was but one member of a committee which found, or thought it found, evidences of the guilt of Hastings; and, in forming his opinion, it is little likely that he should have been biased by interest or resentment, whose delicate sense of rectitude would not permit him to retain a pension when he could no longer support the party of that friend who had obtained it for him.

When the establishment of a regency was thought necessary, he took the part, as it was called, of the Prince of Wales, in opposition to the plan proposed by Lord Thurlow and the minister; and we doubt not but he was actuated by the purest principles: but the language which he used in the house was vehement,

and some of his expressions were highly indecent. Our regard for his memory makes us wish to forget them.

Burke.

Soon after the recovery of the king, the attention of Burke was attracted to the most momentous event of modern times;—an event which has convulsed all Europe, and of which, from the very first, his sagacity foresaw the consequences. Many of his friends in Parliament, as well as numbers of wise and good men out of it, augured, from the meeting of the states-general of France, great benefit to that nation, of which the government was considered as despotic and oppressive; and some were sanguine enough to prognosticate a new and happy order of things to all the nations connected with France, when its government should become more free. Burke thought very differently: He was well acquainted with the genius of the French people, and with the principles of those philosophers, as they called themselves, by whom a total revolution in church and state had long been projected; and from the commencement of their career in the constituent assembly, when they established, as the foundation of all legal government, the metaphysical doctrine of *the rights of man*, he predicted that torrent of anarchy and irreligion which they have since attempted to pour over all Europe. Fox and some of the other leading men in opposition affected to consider this as a vain fear; and a coolness took place between them and Burke, though they still acted together in Parliament. At last, perceiving the French doctrines of liberty and equality, and atheism, spreading through this nation, not only among those who had talents for such disquisitions, but in clubs and societies, of which the members could be no judges of metaphysical reasonings, he expressed his apprehension of the consequences in the house of commons. This brought on a violent altercation between him and Fox, who was supported by Sheridan; and a rupture took place between these old friends which was never healed. He no more attended the meetings of the opposition members; and in 1790 he published his celebrated *Reflections on the French Revolution*.

By the friends of government this work was admired as the most seasonable, as well as one of the ablest, defences of the British constitution that ever was written; whilst Fox and his friends, with the great body of English dissenters, though they admitted it to be the offspring of uncommon genius, affected to consider it as declamatory rather than argumentative, and as inconsistent with the principles which its author had hitherto uniformly maintained. Many answers were written to it; of which the most conspicuous were *Vindiciæ Gallicæ* by Mr Mac Intosh, and *The Rights of Man* by Thomas Paine. To these Burke deigned not to make a direct reply. He vindicated his general principles, as well as some of his particular reasonings, in *A Letter to a Member of the National Assembly*; and he very completely evinced the consistency of his principles in his *Appeal from the New to the Old Whigs*.

Of this great work, for great it undoubtedly is, the merits as well as the demerits have been much exaggerated; and some have made it a question, Whether it has on the whole been productive of good or harm? By the enemies of the author, it is represented as having given rise to the spirit of discontent, by exciting such writers as Paine and his adherents, who, but for the provocation given by *The Reflections*, might have remained

Burke. remained in silence and obscurity. This was from the first a very improbable supposition; for the spirit of democracy has at all times been restless: but since the appearance of Professor Robison's *Proofs of a Conspiracy*, and Barruel's *History of Jacobinism*, it must be known to every reader to be a supposition contrary to fact. The conspirators were busy long before Burke wrote his *Reflections*; and the friends of order and religion are his debtors, for having so forcibly roused them from their slumber, and put them on their guard. With respect to composition, it is certainly neither so energetic nor so argumentative as the political tracts of Johnson, to which some have affected to consider it as superior; but it is more poetical, gives scope for a greater display of the knowledge of human nature; and, being written on a more interesting subject, it has had a much greater number of readers than those unrivalled pieces of political controversy.

Burke being now associated with Mr Pitt, continued to write from time to time memorials and remarks on the state of France, and the alliance that was formed against the new order of things in that distracted country, of which some have been published since his death; and having resolved to quit the bustle of public life as soon as the trial of Mr Hastings should be concluded, he vacated his seat when that gentleman was acquitted, and retired to his villa at Beaconsfield, where, on the 2d of August 1794, he met with a heavy domestic loss in the death of his only son. In the beginning of the same year he had lost his brother Richard, whom he tenderly loved: but though this reiterated stroke of death deeply affected him, it never relaxed the vigour of his mind, nor lessened the interest which he took in the public weal.

In this retreat, while he was labouring for the good of all around him, he was disturbed by a very unprovoked attack upon his character by some distinguished speakers in the house of Peers. Soon after the death of his son the king was graciously pleased to bestow a pension on him and Mrs Burke; and this those noble lords were pleased to represent as the reward of what they termed the change of his principles and the desertion of his friends. The injustice of this charge must be obvious to every impartial mind, since the pension was given after he had retired from parliament, and could not by his eloquence either support the ministry or gall the opposition. He was not a man to submit tamely to such an insult. He published a letter on the occasion, addressed to a noble lord (Earl Fitzwilliam), in which he repels the attack on his character, and retaliates on those by whom it was made, in terms of such eloquent and keen sarcasm, as will be read with admiration as long as the language of the letter shall be understood.

Burke having employed every effort which benevolence and wisdom could devise to stimulate civilized governments to unite in opposition to the impiety and anarchy of France, laboured likewise in private to relieve those who had suffered exile and proscription from the direful system. Through his influence a school was established in his neighbourhood for the education of those whose parents, for their adherence to principle, were rendered unable to afford to their children useful instruction; and that school, which on his deathbed he recommended to Mr Pitt, continues to flourish under his powerful protection.

When the appearance of melioration in the principles and government of France induced our sovereign to make overtures of peace to the French directory, Burke resumed his pen; and in a series of letters, intitled, *Thoughts on the Prospects of a Regicide Peace*, displayed a force of genius which is certainly not surpassed, and perhaps not equalled, even in his far-famed *Reflections on the French Revolution*. This was his last work, and was considered by himself as in its nature testamentary.

From the beginning of June 1797 his health rapidly declined; but his understanding exerted itself with undiminished force and uncontracted range; and his dispositions retained all their amiable sweetness. On the 7th of July, when the French revolution was mentioned, he spoke with pleasure of the conscious rectitude of his own intentions in what he had done and written respecting it; entreated those about him to believe, that if any unguarded expression of his on the subject had offended any of his former friends, no offence was by him intended; and he declared his unfeigned forgiveness of all who had on account of his writings, or for any other cause, endeavoured to do him an injury. On the day following he desired to be carried to another room; and whilst one of his friends, assisted by some servants, was complying with his request, Mr Burke faintly uttering, "God bless you," fell back and expired in the 68th year of his age.

From this detail, we trust that our readers are already sufficiently acquainted with his general character. In genius, variety of knowledge, and readiness of expression, Johnson alone of all his contemporaries could be considered as his rival; and, like that great man, he took every opportunity, especially during his last illness, to declare his unshaken belief of the Christian religion, his veneration for sincere Christians of all persuasions, and his own preference of the church of England. On the worship of that church he had indeed through the whole of his life been a regular and devout attendant; and the tears which the poor, in the neighbourhood of his villa, shed at his funeral, gave sufficient evidence that his faith had been productive of charity. In his public conduct, the irritability of his temper, and the ardour of his imagination, sometimes hurried him into the excesses of a mere party-man; but we believe that his great religious and political principles never varied. He has himself characterised his public conduct in the conclusion of his *Reflections on the French Revolution*, when he says, that "they come from one who has been no tool of power, no flatterer of greatness, and who in his last acts does not wish to belie the tenor of his life; from one who wishes to preserve consistency, but who would preserve consistency by varying his means to secure the unity of his end; and when the equipoise of the vessel in which he sails may be endangered by overloading it upon one side, is desirous of carrying the small weight of his reasons to that which may preserve the equipoise."

BURNET (James, Esq;), better known by the title of *Lord Monboddo*, descended from an ancient family in the county of Mearns in Scotland. He was the eldest son of Arthur Burnet, Esq; of Monboddo, where he was born in the year 1714. After passing through the usual course of school education, he prosecuted his studies at the universities of Aberdeen, Edinburgh, and Leyden,

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Leyden, with distinguished reputation. He was admitted an advocate in 1737; and on the 12th of February 1767, he was raised to the bench, by the title of Lord Monboddo, in the room of Lord Milton, appointed a judge the 4th of June 1742, and who had succeeded Sir John Lauder of Fountainhall, admitted November 1. 1689; so that he was only the third judge in succession since the revolution.

Before his promotion to the bench, he had married Miss Farquharson, a very amiable woman, by whom he had a son and two daughters; whom, without regarding the difference of climate, he reared as the children of ancient Greece were reared.

From early youth Lord Monboddo's application to literary and juridical studies was severely diligent. Between classical literature and the law of Scotland, there exists a strong connection, arising from the adoption of the forms and maxims of the civil law of the Romans, by the ancient legislators and judges of Scotland. Accordingly, while Mr Burnet rose into reputation as a lawyer, he at the same time improved into profound erudition that knowledge of the Greek and Roman authors which he had acquired at school and the university; and his partiality to the Greek language could not fail to be strengthened by his frequent conversations with Dr Blackwell, the celebrated professor of that language in the Marischal College and University of Aberdeen.

His favourite studies, however, were not suffered to interfere with his duty as a judge. In his native country, his integrity as *Sheriff* will be long remembered; and during the whole time that he was a Lord of Session, he discharged the duties of his high office with an assiduity, a patience, a clear intelligence, and inflexible rectitude, which did honour to the court of which he was a judge. Like others, he was liable to error; but neither the awe of power, the blandishments of flattery, nor even compassion for distress, could turn Lord Monboddo aside from what he believed to be the course of justice.

Several of the judges of the court of session were at that period ambitious of shining among philosophers and men of taste; and Lord Kames's *Elements of Criticism* is a work which will be long read, and always admired. It was not, however, admired by Lord Monboddo; and he determined to vindicate the superiority of the ancients over the moderns, as well in philosophy as in belles lettres. With this view he published, in 1773, the first volume of his *ORIGIN AND PROGRESS OF LANGUAGE*; which was perused with mingled sentiments of respect and indignation. It was better received in England than in his own country; and notwithstanding the ridicule brought upon him by his belief in the existence of *mermen*, and *men with tails*, the author felt himself sufficiently encouraged to complete his plan in five volumes.

Having, as he thought, vindicated *Grecian literature*, he was induced to undertake another great work in defence of *Grecian philosophy*, against the still more arrogant claims, as he deemed them, of Bacon and Newton, with their followers. With this view, he published, at different times, and in six volumes 4to, a work intitled *Ancient Metaphysics*, fraught, it must be confessed, with much erudition, much good sense, and, strange as the combination may seem, with much absurdity. In

the preface to the first volume, he declares open war against all modern writers of philosophy, except Mr Harris, who was an adorer of the ancients like himself, Mr Baxter, and Dr Cudworth. He acknowledges Baxter's book on the Immateriality of the Soul to be a truly valuable work; and says of Cudworth's *Intellectual System*, that he agrees with it throughout. There is indeed such a coincidence of notions in the *Intellectual System* and the *Ancient Metaphysics*, that an ill-natured critic might be tempted to suspect, that every thing valuable in the latter was borrowed from the former.

The *Ancient Metaphysics* had few admirers in Scotland; but it procured for its author, from a scholar of Oxford, we think Mr Huntingford, the title of *αλλος Αριστοτελης*. His Lordship continued to cultivate what he called *Greek philosophy*, and to attend his judicial duties, with indefatigable diligence till within a few days of his death, which happened at his house in Edinburgh, on the 26th of May 1799, at the advanced age of 85.

His private life was spent in the practice of all the social virtues, and in the enjoyment of much domestic felicity. Although rigidly temperate in his habits of life, he, however, delighted much in the convivial society of his friends; and among these he could number almost all the most eminent of those who were distinguished in Scotland for virtue, literature, or genuine elegance of conversation and manners. His son, a very promising boy, in whose education he took great delight, was snatched away from his affections by a premature death. But when it was too late for sorrow and anxiety to avail, the afflicted father stifled the emotions of nature in his breast, and wound up the energies of his soul to the firmest tone of stoical fortitude. He was, in like manner, bereaved of his excellent lady, the object of his dearest tenderness; and he endured the loss with a similar firmness, fitted to do honour either to philosophy or to religion. In addition to his office as a judge in the court of session, an offer was made to him of a seat in the court of judicary. But though the emoluments of the office would have made a convenient addition to his income, he refused to accept it, lest its business should too much detach him from the pursuit of his favourite studies.

The vacations of the court of session afforded him sufficient leisure to retire every year, in spring and in autumn, to the country; and he used then to dress in a style of simplicity, as if he had been only a plain farmer; and to live among the people upon his estate with all the kind familiarity and attention of an aged father among his grown-up children. Although the estate, from the old leases, did not afford an income of more than three or four hundred pounds a-year, he would never raise the rents upon his old tenants, nor displace an old tenant, for the sake of any augmentation of emolument offered by a richer or more enterprising stranger. In imitation of the rural economy of some of the ancients, whom he chiefly admired, he accounted population the true wealth of an estate, and was desirous of no other improvement of his lands, than that of having the number of persons that should reside upon them, and be sustained by their produce, superior to that of the population of any equal portion of the lands of his neighbours.

It was at Monboddo that he had the pleasure of receiving Dr Samuel Johnson, with his friend James Boswell, at the time when these two gentlemen were upon

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upon their well-known Tour through the Highlands of Scotland. Johnson admired nothing in literature so much as the display of a keen discrimination of human character, a just apprehension of the principles of moral action, and that vigorous common sense which is the most happily applicable to the ordinary conduct of life. Monboddo delighted in the refinements, the subtleties, the abstractions, the affectations, of literature; and, in comparison with these, despised the grossness of modern taste and of common affairs. Johnson thought learning and science to be little valuable, except so far as they could be made subservient to the purposes of living usefully and happily with the world upon its own terms. Monboddo's favourite science taught him to look down with contempt upon all sublunary, and especially upon all modern things; and to fit life to literature and philosophy, not literature and philosophy to life. James Boswell, therefore, in carrying Johnson to visit Monboddo, probably thought of *putting* them one against another, as two game cocks, and promised himself much sport from the colloquial contest which he expected to ensue between them. But Monboddo was too hospitable and courteous to enter into keen contention with a stranger in his own house. There was much talk between them, but no angry controversy, no exasperation of that dislike for each other's well-known peculiarities with which they had met. Johnson, it is true, still continued to think Lord Monboddo what he called a *prig* in literature; and Monboddo to censure Johnson for allowing the moderns, in some things, to surpass the ancients.

Lord Monboddo used frequently to visit London, to which he was allured by the opportunity that great metropolis affords of enjoying the conversation of a vast number of men of profound erudition. A journey to the capital became a favourite amusement of his periods of vacation from the business of the court to which he belonged; and, for a time, he made this journey once a-year. A carriage, a vehicle that was not in common use among the ancients, he considered as an engine of effeminacy and sloth, which it was disgraceful for a man to make use of in travelling. To be dragged at the tail of a horse, instead of mounting upon his back, seemed, in his eyes, to be a truly ludicrous degradation of the genuine dignity of human nature. In all his journeys, therefore, between Edinburgh and London, he was wont to ride on horseback, with a single servant attending him. He continued this practice, without finding it too fatiguing for his strength, till he was upwards of eighty years of age. Within a few years of his death, on his return from a last visit, which he made on purpose to take leave of all his old friends in London, he became exceedingly ill upon the road, and was unable to proceed; and had he not been overtaken by a Scotch friend, who prevailed upon him to travel the remainder of the way in a carriage, he might perhaps have actually perished by the way-side, or breathed his last in some dirty inn.

In London, his visits were exceedingly acceptable to all his friends, whether of the literary or fashionable world. He delighted to shew himself at court; and the king is said to have taken a pleasure in conversing with the old man with a distinguishing notice that could not but be very flattering to him. He used to mingle, with great satisfaction, with the learned and the inge-

nious, at the house of Mrs Montague. However, after the death of his friend Mr Harris, he found a very sensible diminution of the pleasure he had been wont to enjoy in the society of London.

A constitution of body, naturally framed to wear well and last long, was strengthened to Lord Monboddo by exercise, guarded by temperance, and by a tenor of mind too firm to be deeply broken in upon by those passions which consume the principles of life. In the country he always used much the exercises of walking in the open air and of riding. The cold bath was a means of preserving the health, to which he had recourse in all seasons, amid every severity of the weather, and under every inconvenience of indisposition or business, with a perseverance invincible. He was accustomed, alike in winter and in summer, to rise at a very early hour in the morning, and, without loss of time, to betake himself to study or wholesome exercise. It is said that he even found the use of what he called the air bath, or the practice of occasionally walking about, for some minutes, naked, in a room filled with fresh and cool air, to be highly salutary. In a word, if his peculiarities were striking, his virtues, and learning, and talents, were equally striking; and, taken altogether, he must be considered as a great and a good man.

BURNS (Robert), was a native of Airshire, one of the western counties of Scotland. He was the son of humble parents; and his father passed through life in the condition of a hired labourer, or of a small farmer. Even in this situation, however, it was not hard for him to send his children to the parish-school, to receive the ordinary instruction in reading, writing, arithmetic, and the principles of religion. By this course of education young Robert profited to a degree that might have encouraged his friends to destine him to one of the liberal professions, had not his father's poverty made it necessary to remove him from school, as soon as he had grown up, to earn for himself the means of support as a hired ploughboy or shepherd.

The expence of education in the parish-schools of Scotland is so small, that hardly any parents who are able to labour want the means of giving to their children at least such education as young Burns received. From the spring labours of a ploughboy, from the summer employment of a shepherd, the peasant-youth often returns for a few months, eagerly to pursue his education at the parish-school.

It was so with Burns: he returned from labour to learning, and from learning went again to labour, till his mind began to open to the charms of taste and knowledge; till he began to feel a passion for books, and for the subjects of books, which was to give a colour to the whole thread of his future life. On nature he soon began to gaze with new discernment and with new enthusiasm: his mind's eye opened to perceive affecting beauty and sublimity, where, by the mere gross peasant, there was nought to be seen but water, earth, and sky—but animals, plants, and soil.

What might perhaps first contribute to dispose his mind to poetical efforts, is one particular in the devotional piety of the Scottish peasantry; it is still common for them to make their children get by heart the Psalms of David, in that version of homely rhymes which is used in their churches. In the morning and in the evening of every day, or at least on the evening

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Still more interesting to the young peasantry are those ancient ballads of love and war, of which a great number are, in the south of Scotland, yet popularly known, and often sung by the rustic maid or matron at her spinning-wheel. They are listened to with ravished ears by old and young. Their rude melody; that mingled curiosity and awe which are naturally excited by the very idea of their antiquity; the exquisitely tender and natural complaints sometimes poured forth in them; the gallant deeds of knightly heroism, which they sometimes celebrate; their wild tales of demons, ghosts, and fairies, in whose existence superstition alone has believed; the manners which they represent; the obsolete, yet picturesque and expressive, language in which they are often clothed—give them wonderful power to transport every imagination, and to agitate every heart. To the soul of Burns they were like a happy breeze touching the wires of an Æolian harp, and calling forth the most ravishing melody.

Beside all this, the Gentle Shepherd, and the other poems of Allan Ramsay, have long been highly popular in Scotland. They fell early into the hands of Burns; and while the fond applause which they received drew his emulation, they presented to him likewise treasures of phraseology and models of versification. He got acquainted at the same time with the poetry of Robert Ferguson, written chiefly in the Scottish dialect, and exhibiting many specimens of uncommon poetical excellence. The Seasons of Thomson too, the Grave of Blair, the far-famed Elegy of Gray, the Paradise Lost of Milton, perhaps the Minstrel of Beattie, were so commonly read, even among those with whom Burns would naturally associate, that poetical curiosity, although even less ardent than his, could in such circumstances have little difficulty in procuring them.

With such means to give his imagination a poetical bias, and to favour the culture of his taste and genius, Burns gradually became a poet. He was not, however, one of those forward children who, from a mistaken impulse, begin prematurely to write and to rhyme, and hence never attain to excellence. Conversing familiarly for a long while with the works of those poets who were known to him; contemplating the aspect of nature in a district which exhibits an uncommon assem-

blage of the beautiful and the ruggedly grand, of the cultivated and the wild; looking upon human life with an eye quick and keen, to remark as well the stronger and leading, as the nicer and subordinate, features of character; to discriminate the generous, the honourable, the manly, in conduct, from the ridiculous, the base, and the mean—he was distinguished among his fellows for extraordinary intelligence, good sense, and penetration, long before others, or perhaps even himself, suspected him to be capable of writing verses. His mind was mature, and well stored with such knowledge as lay within his reach: he had made himself master of powers of language, superior to those of almost any former writer in the Scottish dialect, before he conceived the idea of surpassing Ramsay and Ferguson.

Hitherto he had conversed intimately only with peasants on his own level; but having got admission into the fraternity of free masons, he had the fortune, whether good or bad, to attract in the lodges the notice of gentlemen better qualified than his more youthful companions to call forth the powers of his mind, and to show him that he was indeed a poet. A masonic song, a satirical epigram, a rhyming epistle to a friend, attempted with success, taught him to know his own powers, and gave him confidence to try tasks more arduous, and which should command still higher bursts of applause.

The annual celebration of the sacrament of the Lord's Supper, in the rural parishes of Scotland, has much in it of those old popish festivals, in which superstition, traffic, and amusement, used to be strangely intermingled. Burns saw, and seized in it one of the happiest of all subjects, to afford scope for the display of that strong and piercing sagacity by which he could almost intuitively distinguish the reasonable from the absurd, and the becoming from the ridiculous; of that picturesque power of fancy, which enabled him to represent scenes, and persons, and groupes, and looks, attitude, and gestures, in a manner almost as lively and impressive, even in words, as if all the artifices and energies of the pencil had been employed; of that knowledge which he had necessarily acquired of the manners, passions, and prejudices of the rustics around him, of whatever was ridiculous, no less than of whatever was affectingly beautiful in rural life.

A thousand prejudices of Popish, and perhaps too of ruder Pagan superstition, have from time immemorial been connected in the minds of the Scottish peasantry, with the annual recurrence of the Eve of the Festival of all the Saints or Halloween. These were all intimately known to Burns, and had made a powerful impression upon his imagination and feelings. He chose them for the subject of a poem, and produced a piece which is almost to frenzy the delight of those who are best acquainted with its subject; and which will not fail to preserve the memory of the prejudices and usages which it describes, when they shall perhaps have ceased to give one merry evening in the year to the cottage fire-side.

The simple joys, the honest love, the sincere friendship, the ardent devotion of the cottage; whatever in the more solemn part of the rustic's life is humble and artless, without being mean or unseemly—or tender and dignified, without aspiring to stilted grandeur—or to unnatural, buskined pathos, had deeply impressed the imagination

imagination of the rising poet; had, in some sort, wrought itself into the very texture of the fibres of his soul. He tried to express in verse what he most tenderly felt, what he most enthusiastically imagined; and produced the *Cottar's Saturday Night*.

These pieces, the true effusions of genius, informed by reading and observation, and prompted by its own native ardour, as well as by friendly applause, were soon handed about among the most discerning of Burns's acquaintance; and were by every new reader perused, and reperused, with an eagerness of delight and approbation which would not suffer their author long to withhold them from the press. A subscription was proposed, was earnestly promoted by some gentlemen, who were glad to interest themselves in behalf of such signal poetical merit; was soon crowded with the names of a considerable number of the inhabitants of Airshire, who in the proffered purchase sought not less to gratify their own passion for Scottish poesy, than to encourage the wonderful ploughman. At Kilmarnock were the poems of Burns for the first time printed. The whole edition was quickly distributed over the country.

It is hardly possible to express with what eager admiration and delight they were everywhere received.—They eminently possessed all those qualities which the most invariably contribute to render any literary work quickly and permanently popular. They were written in a phraseology, of which all the powers were universally felt; and which being at once antique, familiar, and now rarely written, was hence fitted to serve all the dignified and picturesque uses of poetry, without making it unintelligible. The imagery, the sentiments, were at once faithfully natural, and irresistibly impressive and interesting. Those topics of satire and scandal in which the rustic delights; that humorous imitation of character, and that witty association of ideas familiar and striking, yet not naturally allied to one another, which has force to shake his sides with laughter; those fancies of superstition, at which he still wonders and trembles; those affecting sentiments and images of true religion, which are at once dear and awful to his heart—were all represented by Burns with all a poet's magic power. Old and young, high and low, grave and gay, learned or ignorant, all were alike delighted, agitated, transported.

In the mean time, some few copies of these fascinating poems found their way to Edinburgh; and having been read to Dr Blacklock, they obtained his warmest approbation. In the beginning of the winter 1786-7 Burns went to Edinburgh, where he was received by Dr Blacklock with the most flattering kindness, and introduced to every man of generosity and taste among that good man's friends. Multitudes now vied with each other in patronizing the rustic poet. Those who possessed at once true taste and ardent philanthropy were soon earnestly united in his praise: they who were disposed to favour any good thing belonging to Scotland, purely because it was Scottish, gladly joined the cry; those who had hearts and understanding to be charmed, without knowing why, when they saw their native customs, manners, and language, made the subjects and the materials of poesy, could not suppress that voice of feeling which struggled to declare itself for Burns: for the dissipated, the licentious, the malignant wits, and the freethinkers, he was so unfortunate as to

have satire, and obscenity, and ridicule of things sacred, sufficient to captivate their fancies; even for the pious he had passages in which the inspired language of devotion might seem to come mended from his pen.

Thus did Burns, ere he had been many weeks in Edinburgh, find himself the object of universal curiosity, favour, admiration, and fondness. He was sought after, courted with attentions the most respectful and assiduous, feasted, flattered, caressed, treated by all ranks as the first boast of his country, whom it was scarcely possible to honour and reward to a degree equal to his merits. In comparison with the general favour which now promised to more than crown his most sanguine hopes, it could hardly be called praise at all which he had obtained in Airshire.

In this posture of our poet's affairs a new edition of his poems was earnestly called for. He sold the copy-right for one hundred pounds; but his friends at the same time suggested, and actively promoted, a subscription for an edition, to be published for the benefit of the author, ere the bookseller's right should commence. Those gentlemen who had formerly entertained the public of Edinburgh with the periodical publication of the papers of the *Mirror*, having again combined their talents in producing the *Lounger*, were at this time about to conclude this last series of papers; yet before the *Lounger* relinquished his pen, he dedicated a number to a commendatory criticism of the poems of the Airshire bard.

The subscription-papers were rapidly filled; and it was supposed that the poet might derive from the subscription and the sale of his copy-right a clear profit of at least 700 pounds.

The conversation of even the most eminent authors is often found to be so unequal to the fame of their writings, that he who reads with admiration can listen with none but sentiments of the most profound contempt. But the conversation of Burns was, in comparison with the formal and exterior circumstances of his education, perhaps even more wonderful than his poetry. He affected no soft air or graceful motions of politeness, which might have ill accorded with the rustic plainness of his native manners. Conscious superiority of mind taught him to associate with the great, the learned, and the gay, without being overawed into any such bashfulness as might have made him confused in thought, or hesitating in elocution. He possessed withal an extraordinary share of plain common sense or mother-wit, which prevented him from obtruding upon persons, of whatever rank with whom he was admitted to converse, any of those effusions of vanity, envy, or self-conceit, in which authors are exceedingly apt to indulge, who have lived remote from the general practice of life, and whose minds have been almost exclusively confined to contemplate their own studies and their own works. In conversation he displayed a sort of intuitive quickness and rectitude of judgment upon every subject that arose. The sensibility of his heart, and the vivacity of his fancy, gave a rich colouring to whatever reasoning he was disposed to advance; and his language in conversation was not at all less happy than in his writings. For these reasons, those who had met and conversed with him once, were pleased to meet and to converse with him again and again.

For some time he conversed only with the virtuous,

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the learned, and the wife; and the purity of his morals remained uncontaminated. But, alas! he fell, as others have fallen in similar circumstances. He suffered himself to be surrounded by a race of miserable beings, who were proud to tell that they had been in company with Burns, and had seen Burns as loose and as foolish as themselves. He was not yet irrecoverably lost to temperance and moderation; but he was already almost too much captivated with their wanton revels, to be ever more won back to a faithful attachment to their more sober charms. He now also began to contract something of new arrogance in conversation. Accustomed to be among his favourite associates what is vulgarly but expressively called *the cock of the company*, he could scarcely refrain from indulging in similar freedom and dictatorial decision of talk, even in the presence of persons who could less patiently endure his presumption.

The subscription-edition of his poems, in the mean time, appeared; and although not enlarged beyond that which came from the Kilmarnock press by any new pieces of eminent merit, did not fail to give entire satisfaction to the subscribers. He was now to close accounts with his bookseller and his printer, to retire to the country with his profits in his pocket, and to fix upon a plan for his future life. He talked loudly of independence of spirit and simplicity of manners, and boasted his resolution to return to the plough; yet still he lingered in Edinburgh, week after week, and month after month, perhaps expecting that one or other of his noble patrons might procure him some permanent and competent annual income, which should set him above all necessity of future exertions to earn for himself the means of subsistence; perhaps unconsciously reluctant to quit the pleasures of that voluptuous town-life to which he had for some time too willingly accustomed himself. An accidental dislocation or fracture of an arm or a leg confining him for some weeks to his apartment, left him during this time leisure for serious reflection; and he determined to retire from the town without longer delay. None of all his patrons interposed to divert him from his purpose of returning to the plough, by the offer of any small pension, or any sinecure place of moderate emolument, such as might have given him competence without withdrawing him from his poetical studies. It seemed to be forgotten that a ploughman thus exalted into a man of letters was unfitted for his former toils, without being regularly qualified to enter the career of any new profession; and that it became incumbent upon those patrons who had called him from the plough, not merely to make him their companion in the hour of riot, not simply to fill his purse with gold for a few transient expences, but to secure him as far as was possible from being ever overwhelmed in distress in consequence of the favour which they had shown him, and of the habits of life into which they had seduced him. Perhaps indeed the same delusion of fancy betrayed both Burns and his patrons into the mistaken idea, that, after all which had passed, it was still possible for him to return in cheerful content to the homely joys and simple toils of undissipated rural life.

In this temper of Burns's mind, in this state of his fortune, a farm and the excise were the objects upon which his choice ultimately fixed for future employment and support. By the surgeon who attended him during

Burns.

his illness, he was recommended with effect to the commissioners of excise; and Patrick Millar, Esq. of Dalswinton, deceived, like Burns himself and Burns's other friends, into an idea that the poet and exciseman might yet be respectable and happy as a farmer, generously proposed to establish him in a farm, upon conditions of lease which prudence and industry might easily render exceedingly advantageous. Burns eagerly accepted the offers of this benevolent patron. Two of the poet's friends from Airshire were invited to survey that farm in Dumfriesshire which Mr Millar offered. A lease was granted to the poetical farmer at that annual rent which his own friends declared that the due cultivation of his farm might easily enable him to pay. What yet remained of the profits of his publication was laid out in the purchase of farm-stock; and Mr Millar might, for some short time, please himself with the persuasion that he had approved himself the liberal patron of genius; had acquired a good tenant upon his estate; and had placed a deserving man in the very situation in which alone he himself desired to be placed, in order to be happy to his wishes.

Burns, with his Jane, whom he now married, took up their residence upon his farm. The neighbouring farmers and gentlemen, pleased to obtain for an inmate among them the poet by whose works they had been delighted, kindly sought his company, and invited him to their houses. He found an inexpressible charm in sitting down beside his wife, at his own fireside; in wandering over his own grounds; in once more putting his hand to the spade and the plough; in forming his enclosures, and managing his cattle. For some months he felt almost all that felicity which fancy had taught him to expect in his new situation. He had been for a time idle; but his muscles were not yet unbraced for rural toil. He now seemed to find a joy in being the husband of the mistress of his affections, in seeing himself the father of her children, such as might promise to attach him for ever to that modest, humble, and domestic life, in which alone he could hope to be permanently happy. Even his engagements in the service of the excise did not, at the very first, threaten necessarily to debase him by association with the mean, the gross, and the profligate, to contaminate the poet, or to ruin the farmer.

But it could not be: it was not possible for Burns now to assume that soberness of fancy and passions, that sedateness of feeling, those habits of earnest attention to gross and vulgar cares, without which success in his new situation was not to be expected. A thousand difficulties were to be encountered and overcome, much money was to be expended, much weary toil was to be exercised, before his farm could be brought into a state of cultivation in which its produce might enrich the occupier. This was not a prospect encouraging to a man who had never loved labour, and who was at this time certainly not at all disposed to enter into agriculture with the enthusiasm of a projector. The business of the excise too, as he began to be more and more employed in it, distracted his mind from the care of his farm, led him into gross and vulgar society, and exposed him to many unavoidable temptations to drunken excess, such as he had no longer sufficient fortitude to resist. Amidst the anxieties, distractions, and seducements which thus arose to him, home became insensibly less and less pleasing

Burns. sing; even the endearments of his Jane's affection began to lose their hold on his heart; he became every day less and less unwilling to forget in riot those gathering sorrows which he knew not to subdue.

Mr Millar and some others of his friends would gladly have exerted an influence over his mind which might have preserved him in this situation of his affairs, equally from profligacy and from dissipation; but Burns's temper spurned all controul from his superiors in fortune. He resented, as an arrogant encroachment upon his independence, that tenor of conduct by which Mr Millar wished to turn him from dissolute conviviality, to that steady attention to the business of his farm, without which it was impossible to thrive in it. His crosses and disappointments drove him every day more and more into dissipation; and this dissipation tended to enhance whatever was disagreeable and perplexing in the state of his affairs. He sunk, by degrees, into the boon companion of mere excisemen; and almost every drunken fellow, who was willing to spend his money lavishly in the alehouse, could easily command the company of Burns. The care of his farm was thus neglected; waste and losses wholly consumed his little capital; he resigned his lease into the hands of his landlord; and retired, with his family, to the town of Dumfries, determining to depend entirely for the means of future support upon his income as an excise-officer.

Yet during this unfortunate period of his life, which passed between his departure from Edinburgh to settle in Dumfriesshire, and his leaving the country, in order to take up his residence in the town of Dumfries, the energy and activity of his intellectual powers appeared to have been not at all impaired. In a collection of Scottish songs, which were published (the words with the music) by Mr Johnson, engraver in Edinburgh, in 4 vols 8vo, Burns, in many instances, accommodated new verses to the old tunes with admirable felicity and skill. He assisted in the temporary institution of a small subscription library, for the use of a number of the well-disposed peasants in his neighbourhood. He readily aided, and by his knowledge of genuine Scottish phraseology and manners greatly enlightened, the antiquarian researches of the late ingenious Captain Grose. He still carried on an epistolary correspondence, sometimes gay, sportive, humorous, but always enlivened by bright flashes of genius, with a number of his old friends, and on a very wide diversity of topics. At times, as it should seem from his writings of this period, he reflected, with inexpressible heart-bitterness, on the high hopes from which he had fallen; on the errors of moral conduct into which he had been hurried by the ardour of his soul, and in some measure by the very generosity of his nature; on the disgrace and wretchedness into which he saw himself rapidly sinking; on the sorrow with which his misconduct oppressed the heart of his Jane; on the want and destitute misery in which it seemed probable that he must leave her and their infants; nor amidst these agonizing reflections did he fail to look, with an indignation half invidious, half contemptuous, on those who, with moral habits not more excellent than his, with powers of intellect far inferior, yet basked in the sun-shine of fortune, and were loaded with the wealth and honours of the world, while his follies could not obtain pardon, nor his wants an honourable supply. His wit became from this time more

gloomily sarcastic; and his conversation and writings began to assume something of a tone of misanthropical malignity, by which they had not been before, in any eminent degree, distinguished. But with all these failings, he was still that exalted mind which had raised itself above the depression of its original condition: with all the energy of the lion, pawing to set free his hinder limbs from the yet encumbering earth, he still appeared *not less than archangel ruined!*

His morals were not mended by his removal from the country. In Dumfries his dissipation became still more deeply habitual; he was here more exposed than in the country to be solicited to share the riot of the dissolute and the idle: foolish young men flocked eagerly about him, and from time to time pressed him to drink with them, that they might enjoy his wicked wit. The Caledonian Club, too, and the Dumfriesshire and Galloway Hunt, had occasional meetings in Dumfries after Burns went to reside there, and the poet was of course invited to share their conviviality, and hesitated not to accept the invitation.

In the intervals between his different fits of intemperance, he suffered still the keenest anguish of remorse, and horribly afflictive foresight. His Jane still behaved with a degree of maternal and conjugal tenderness and prudence, which made him feel more bitterly the evil of his misconduct, although they could not reclaim him. At last crippled, emaciated, having the very power of animation wasted by disease, quite broken-hearted by the sense of his errors, and of the hopeless miseries in which he saw himself and his family depressed; with his soul still tremblingly alive to the sense of shame, and to the love of virtue; yet even in the last feebleness, and amid the last agonies of expiring life, yielding readily to any temptation that offered the semblance of intemperate enjoyment, he died at Dumfries, in the summer of 1796, while he was yet three or four years under the age of forty, furnishing a melancholy proof of the danger of *suddenly* elevating even the greatest mind above its original level.

After his death, it quickly appeared that his failings had not effaced from the minds of his more respectable acquaintance either the regard which had once been won by his social qualities, or the reverence due to his intellectual talents. The circumstances of want in which he left his family were noticed by the gentlemen of Dumfries with earnest commiseration. His funeral was celebrated by the care of his friends with a decent solemnity, and with a numerous attendance of mourners, sufficiently honourable to his memory. Several copies of verses were inserted in different newspapers upon the occasion of his death. A contribution, by subscription, was proposed, for the purpose of raising a small fund, for the decent support of his widow, and the education of his infant children.

From the preceding detail of the particulars of this poet's life, the reader will naturally and justly infer him to have been an honest, proud, warm-hearted man; of high passions and sound understanding, and a vigorous and exursive imagination. He was never known to descend to any act of deliberate meanness. In Dumfries he retained many respectable friends even to the last; and it may be doubted whether any poet of the present age has exercised a greater power over the minds of his readers. Burns has not failed to command

Burrampooter, Butter. one remarkable sort of homage, such as is never paid but to great original genius; a crowd of poets afterwards started up to imitate him, by writing verses as he had done in the Scottish dialect; but, *O imitatores! servum pecus!* To write rugged rhimes, in antiquated phrase, is not to imitate the poetry of Burns.

BURRAMPOOTER. See SANDPU, *Encycl.*

BUTTER is a substance so well known, that it is needless to give here any definition of it; but as it is, in this country at least, so general an article of food, that the proper methods of making and curing it have engaged the attention of some of our ablest writers on agriculture, in addition to what has been said on these subjects under the titles **BUTTER** and **DAIRY** (*Encycl.*) our readers will probably be pleased with the following method of curing it, which is practised by some farmers in the parish of Udney, in the county of Aberdeen, and gives to their butter a great superiority above that of their neighbours.

Take two parts of the best common salt, one part of sugar, and one part of saltpetre; beat them up together, and blend the whole completely. Take one ounce of this composition for every 16 ounces of butter, work it well into the mass, and close it up for use.

Dr James Anderson, from whose View of the Agriculture of the County of Aberdeen this receipt is taken, says, that he knows of no simple improvement in economics greater than this is, when compared with the usual mode of curing butter by means of common salt alone. "I have seen (continues he) the experiment fairly made, of one part of the butter made at one time being thus cured, and the other part cured with salt alone: the difference was inconceivable. I should suppose that, in any open market, the one would sell for 30 per cent. more than the other. The butter cured

with the mixture appears of a rich marrowy consistence and fine colour, and never acquires a brittle hardness nor tastes salt; the other is comparatively hard and brittle, approaching more nearly to the appearance of tallow, and is much saltier to the taste. I have ate butter cured with the above composition that had been kept three years, and it was as sweet as at first; but it must be noted, that butter thus cured requires to stand three weeks or a month before it is begun to be used. If it be sooner opened, the salts are not sufficiently blended with it; and sometimes the coolness of the nitre will then be perceived, which totally disappears afterwards."

The following observations respecting the proper method of keeping both milk and butter are by the same author, and we trust may prove useful. Speaking still of the county of Aberdeen, he says, "The pernicious practice of keeping milk in leaden vessels, and salting butter in stone jars, begins to gain ground among some of the fine ladies in this county, as well as elsewhere, from an idea of cleanliness. The fact is, it is just the reverse of cleanliness; for in the hands of a careful person nothing can be more cleanly than wooden dishes, but under the management of a flattern they discover the secret which stone dishes indeed do not.

"In return, these latter communicate to the butter and the milk, which has been kept in them, a poisonous quality, which inevitably proves destructive to the human constitution. To the prevalence of this practice I have no doubt we must attribute the frequency of palsies, which begin to prevail so much in this kingdom; for the well known effect of the poison of lead is bodily debility, palsy—death!"

BYSAK, the first month of the Bengal year, beginning in April.

C.

Caffres.

CAFFRES, the inhabitants of Caffraria, are generally confounded with the Hottentots; but, according to M. Vaillant, there is a considerable difference between the manners, customs, and even appearance of these two nations.

The Caffres, says he, are generally taller than the Hottentots, more robust, more fierce, and much bolder. Their figure is likewise more agreeable, and their countenances have not that narrowness at the bottom, nor their cheeks those prominences, which are so disagreeable among the Hottentots. A round figure, a nose not too flat, a broad forehead, and large eyes, give them an open and lively air; and if prejudice can overlook the colour of the skin, there are some Caffre women who, even in Europe, would be accounted pretty. These people do not make their faces ridiculous, by pulling out their eye-brows like the Hottentots; they tattoo themselves much, and particularly their bodies;

their hair, which is frizzled very much, is never greased, but their bodies are liberally anointed, merely with a view to preserve their vigour and agility.

The men generally bestow more attention on their dress than the women, and are remarkably fond of beads and copper rings. The women wear hardly any of the ornaments in which the other savages in Africa take such delight. They do not even wear copper bracelets; but their small aprons, which are still shorter than those of the Hottentots, are bordered with a few rows of glass beads; and in this all their luxury consists. It would appear that the Caffres are not so chaste as the Hottentots, because the men do not use a jackal to veil what nature teaches other men, even savages, to conceal. A small cowl, which covers only the glans, instead of displaying modesty, seems to announce the greatest indecency. This small covering adheres to a thong, which is fastened round their girdles, merely that

Caffres.

that it may not be lost; for a Caffre, if he be not afraid of being hurt or stung by insects, cares very little whether his cowl be in its place or not. Our author saw one Caffre who, instead of a cowl, wore a case made of wood, and ornamented with sculpture. This was a new and ridiculous fashion, which he had borrowed from a nation of black people who lived at a great distance from Caffraria.

In the hot season the Caffres go always naked, and retain nothing but their ornaments. In cold weather they wear krosses made of calves or oxen hides, which reach down to the ground; but whatever the weather be, both sexes go bare-headed, except that they sometimes, though rarely, fix a plume of feathers in their hair.

The Caffre huts are more spacious and higher than those of the Hottentots, and have also a more regular form. The frames of them are constructed of wooden work, well put together, and very solid, being intended to last for a long time: for the Caffres, applying to agriculture, which the free Hottentots do not, remain fixed to one spot, unless something unexpected interrupt their repose.

A more perceptible industry, an acquaintance with some of the most necessary arts of life, a little knowledge of agriculture, and a few religious dogmas, seem to announce that the Caffres approach much nearer to civilization than the Hottentots. They entertain a tolerably exalted idea of the Supreme Being and his power; they believe that the good will be rewarded, and the wicked punished, in a future state; but they have no notion of creation, which indeed was not admitted by the sages of Greece and Rome. They practise circumcision, but can give no account of its origin among them, or of the purpose for which the practice is continued.

Polygamy is used among the Caffres; and on the death of a father the male children and their mothers share the succession among them. The girls remain with their mothers without property of any kind until they can procure husbands. One very singular custom of the Caffres is, that they do not, in general, inter their dead, but transport them from the kraal to an open ditch, which is common to the whole horde. At this ditch savage animals feed at their leisure on the multitude of carcases which are heaped together. Funeral honours are due only to kings and the chiefs of each horde, whose bodies are covered with a heap of stones collected into the form of a dome.

This nation is governed by a general, chief, or king, whose power is very limited. He appoints, however, the subordinate chiefs over the different hordes, and through them communicates his directions or orders. The arms of the Caffre are a *club*, two feet and a half in length, and where thickest three inches in diameter, and a plain lance or *assagey*. He despises poisoned arrows, which are so much used by some of the neighbouring nations; and with his two simple weapons seeks always to meet his enemy face to face in the field. The Hottentot, on the contrary, concealed under a rock or behind a bush, deals out destruction, without being exposed to danger. The one is a perfidious tyger, which rushes treacherously on his prey; the other is a generous lion, which, having given warning of his approach,

makes his attack boldly, and perishes if he prevail not against his antagonist.

CALCULUS, in mathematics, denotes a certain way of performing investigations and resolutions, which occur on many occasions, particularly in mechanical philosophy. Thus we say, the *antecedental* calculus, the *algebraical* calculus, the *arithmetical* calculus, the *differential* calculus, the *exponential* calculus, the *fluxional* calculus, and the *integral* calculus. Of by much the greater part of these calculi some account has been given in the *Encyclopædia Britannica*; but there is one of them, of which no notice has been taken in that work. It is,

The Antecedental CALCULUS, a geometrical method of reasoning, without any consideration of motion or velocity, applicable to every purpose to which the much celebrated doctrine of fluxions of the illustrious Newton has been, or can be, applied. This method was invented by James Glenie, Esq; "in which (he says) every expression is truly and strictly geometrical, is founded on principles frequently made use of by the ancient geometers, principles admitted into the very first elements of geometry, and repeatedly used by EUCLID himself. As it is a branch of general geometrical proportion, or universal comparison, and is derived from an examination of the antecedents of ratios, having given consequents and a given standard of comparison in the various degrees of augmentation and diminution they undergo by composition and decomposition, I have called it the antecedental calculus. As it is purely geometrical, and perfectly scientific, I have, since it first occurred to me in 1779, always made use of it instead of the fluxionary and differential calculi, which are merely arithmetical. Its principles are totally unconnected with the ideas of motion and time, which, strictly speaking, are foreign to pure geometry and abstract science, though, in mixed mathematics and natural philosophy, they are equally applicable to every investigation, involving the consideration of either with the two numerical methods just mentioned. And as many such investigations require compositions and decompositions of ratios, extending greatly beyond the triplicate and subtriplicate, this calculus in all of them furnishes every expression in a strictly geometrical form. The standards of comparison in it may be any magnitudes whatever, and are of course indefinite and innumerable; and the consequents of the ratios, compounded or decomposed, may be either equal or unequal, homogeneous or heterogeneous. In the fluxionary and differential methods, on the other hand, 1, or unit, is not only the standard of comparison, but also the consequent of every ratio compounded or decomposed."

This method is deduced immediately from Mr Glenie's Treatise on the Doctrine of Universal Comparison or General Proportion: And as the limits of the present work will not allow us to enter upon this subject, we therefore refer our readers to the two above mentioned treatises, and to the fourth volume of the Transactions of the Royal Society of Edinburgh.

We confess, however, that we do not expect such great advantage from the employment of this calculus as the very acute and ingenious author seems to promise from it. The mathematical world is truly indebted to him for the clear and discriminating view that he has

taken:

Calculus.

Calendar
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Callao.

taken of the doctrine of universal comparison, and we believe it to be perfectly accurate, and in some respects new. Notwithstanding the continual occupation of mathematicians with ratios and analogies, their particular objects commonly restricted their manner of conceiving ratio to some present modification of it. Hence it seems to have happened that their conceptions of it as a magnitude have not been uniform. But Mr Glenie, by avoiding every peculiarity, has at once attributed to it all the measurable affections of magnitude, addition or subtraction, multiplication or division, and ratio or proportion. He is perhaps the first who has roundly considered ratio or proportion as an affection of ratio; and it is chiefly by the employment of this undoubted affection of ratio that he has rendered the geometrical analysis so comprehensive.

But when we view this antecedental calculus, not as a method of expressing mathematical science, but as an art, as a calculus in short, and consider the means which it must employ, and the notation which must be used, we become less sanguine in our hopes of advantage from it. The notation cannot (we think) be more simple than that of the fluxionary method, justly called *arithmetical*; and if we insist on carrying clear conceptions along with us, we imagine that the arithmetical exposition of our symbols will generally be the simpler of the two. The *science* of the antecedental calculus seems to consist in the attainable perception of all the simple ratios, whether of *magnitudes* or *ratios*, or both, which concur to the formation of a compound and complicated ratio. Now this is equally, and more easily attainable in the fluxionary or other arithmetical method, when the consequent is a simple magnitude. When it is not, the same process is farther necessary in both methods, for getting rid of its complication.

We apprehend that it is a mistake that the geometrical method is more abstracted than the fluxionary, because the latter superadds to the notion of extension the notions of time and motion. These notions were introduced by the illustrious inventor for the *demonstration*, but never occupy the thoughts in the use of his propositions. These are *geometrical* truths, no matter how demonstrated; and when duly considered, involve nothing that is omitted in the antecedental calculus. We even presume to say, that the complication of thought, in the contemplation of the ratios of ratios, is greater than what will generally arise from the additional elements, time and motion.

We do not find that any of our most active mathematicians have availed themselves of the advantages of this calculus, nor do we know any specimen that has been exhibited of its eminent advantages in mathematical discussions. Should it prove more fertile in geometrical expressions of highly compounded or complicated quantities or relations, we should think it a mighty acquisition; being fully convinced that these afford to the memory or imagination an object (we may call it a sensible picture) which it can contemplate and remember with incomparably greater clearness and steadiness than any algebraical formula. We need only appeal to the geometrical expressions of many fluents, which are to be seen in Newton's lunar theory, in the physical tracts of Dr Matthew Stewart, and others who have shewn a partiality for this method.

It would be very presumptuous, however, for us to

say, that the accurate geometer and metaphysician may not derive great advantages from prosecuting the very ingenious and reconditte speculations of Mr Glenie, in his doctrine of universal comparison.

CALENDAR, in chronology. See (*Encycl.*) KALENDAR; and REVOLUTION, n^o 184.

CALIPPIC PERIOD, in chronology, a period of 76 years, continually recurring; at every repetition of which, it was supposed by its inventor Calippus, an Athenian astronomer, that the mean and new full moons would always return to the same day and hour.

About a century before, the golden number, or cycle of 19 years, had been invented by Meton; which Calippus finding to contain 19 of Nabonassar's year, 4 days, and $\frac{3}{4}\frac{3}{5}$, to avoid fractions he quadrupled it, and so produced his period of 76 years, or 4 times 19; after which he supposed all the lunations, &c. would regularly return to the same hour. But neither is this exact, as it brings them too late by a whole day in 225 years.

CALLAO, as it is called by its inhabitants, but more generally known to Europeans under the name of CAMPELLO, is a small island, which was visited by some of Lord Macartney's suite on their voyage to China. In consequence of that visit, we have the following description of it in Sir George Staunton's Account of the Embassy.

"It lies opposite to, and about eight miles to the eastward of, the mouth of a considerable river on the coast of Cochinchina, on the banks of which is situated the town of Fai-foo, a place of some note, not far from the harbour of Turon. The bearing of the highest peak of Callao from this harbour is about south-east, distance thirty miles. The extreme points of the island lie in latitude $15^{\circ} 53'$, and $15^{\circ} 57'$ north; the greatest length is from north-west to south-east, and is somewhat about five miles, and the mean breadth two miles. The only inhabited part is on the south-west coast, on a slip of ground rising gently to the east, and contained between the bottom of a femilunar bay and the mountains on each side of it. Those mountains, at a distance, appear as if they formed two distinct islands. The southern mountain is the highest, and is about 1500 feet. The lower grounds contain about 200 acres. This small but enchanting spot is beautifully diversified with neat houses, temples, clumps of trees, small hillocks swelling from the plain, and richly decorated with shrubbery and trees of various kinds; among which the elegant arca, rising like a Corinthian column, is eminently conspicuous. A rill of clear water, oozing from the mountains, is contrived to be carried along the upper ridges of the vale, from whence it is occasionally conveyed through sluices, for the purpose of watering the rice grounds, and appeared, though then in the dry season, fully sufficient for every purpose for which it could be wanted.

"The houses, in general, were clean and decent; a few were built with stone, and covered with tiles. One, probably the mansion of the chief person of the island, was enclosed by a stone wall, and the approach to it was through a gateway between two stone pillars. The house was divided into a number of apartments, of which the arrangement did not seem to want either taste or convenience. This building stood at the head of the principal village, which consisted of about thirty habitations

Callao. habitations built of wood, chiefly the bamboo. Behind the village, and on the side of the hill, was a cave, accessible only by one way, through an irregular range of rocks. Within the cave, but near its mouth, was a small temple, commanding a view of the whole vale. Several other temples were dispersed over the plain, all of which were open in front, with a colonnade before them of round wooden pillars, painted red and varnished. The number of houses on the island scarcely exceeded sixty. Behind every house, not immediately in the principal village, were enclosures of sugar-canes, tobacco, and other vegetables, growing in great luxuriance. The mountains were covered with verdure, and seemed well calculated for rearing goats, of which the island produced a few.

“ Beside the principal bay, there were several sandy inlets, with small patches of level ground behind them. Boats might easily land in any of these inlets; but a communication between them by land appeared to be exceedingly difficult, if not entirely prevented, by the steep and rugged ridges which separated them from each other. On this account very slight works, and an establishment of a few men only, would be requisite for the defence of the island, a great part of its coast being impregnably fortified by nature. The depth of water in the bay and road was sufficient for ships of any burden, and there was perfect shelter from every wind except the south-west, to which quarter it was directly open. The short distance, however, from the continent in that direction would always prevent the sea from rising high, though it might not be sufficiently near to break the force of the wind.”

The inhabitants of this island are so exceedingly shy and afraid of strangers, that upon the approach of the English vessel, they all, except a very few, retired on board their galleys. When the British landed, therefore, they found the doors of all the houses open, with several domestic animals feeding before them, but neither man, woman, nor child within. After some time, however, a person was perceived lurking among the neighbouring trees, who, finding he was observed, came forward with reluctance and evident marks of fear. While he was yet at some distance, he fell upon his knees, and touched the ground with his forehead several times. On approaching to him, it was noticed that the first joint of every one of his fingers and toes was wanting, and as if twisted off by violence: it was possible that he might have thus been treated by way of punishment for some crime, and that he was considered as the fittest person to be exposed to the supposed danger of watching the movements of the strangers coming ashore. In a little time some others, hidden in the thickets, finding that no mischief was suffered by the first, ventured out. None of them could understand the Chinese interpreter; and not being able to read or write, there was no conversing with them by the medium of the Chinese characters. Recourse was had to hieroglyphics, and rude figures were drawn of the articles which were proposed to be purchased; and this method succeeded tolerably well; poultry and fruits were brought for sale, for which high prices were given, purposely to conciliate the good will of those islanders. The few that were found grew soon familiar; and one old man preferring invited the strangers to his house, situated upon an eminence, at a little distance. On arriving there,

he introduced them to his wife, an old woman, who, after recovering from her astonishment at the sight of figures so different from those she had ever been accustomed to behold, laid, in a neat manner, before them some fruits, sugar, cakes, and water. On departing from the house, this decent and hospitable couple made signs to testify their desire of seeing them again.”

The possession of this island would be of such importance to any European nation who wished to trade securely with TUNG-QUIN and COCHIN CHINA, that it is said the French had formerly some thoughts of purchasing it. Sir George Staunton, however, is of opinion, that the want of shelter in the south-west monsoon would render it of little value, without a further settlement near it upon the main land of Cochin-china: and he thinks, that if a solid establishment there could be productive of advantage to any European nation, it would necessarily be so to Great Britain; because, beside the opening which it would make for the sale of British manufactures among the people of the country, the British possessions in Hindostan would be sure of a very considerable demand for their productions.

CAMEL, in navigation, is a machine which has been described with sufficient accuracy in the Encyclopædia; but the following account of its invention, given by Professor Beckmann, is perhaps not unworthy of a place in this Supplement.

“ In the Zuyder-Zee, opposite to the mouth of the river Y, about six miles from the city of Amsterdam, there are two sand banks, between which is a passage called the *Pampus*, which is sufficiently deep for small ships, but not for such as are large or heavy laden. In 1672 the Dutch contrived, however, to carry their numerous fleet through this passage, by means of large empty chests fastened to the bottom of each ship; and this contrivance gave rise to the invention of the *camel*.” In the Encyclopædia Britannica its invention is given to the famous De Wit; in the German Cyclopædia to Meyer a Dutch engineer of very considerable eminence; but the Dutch writers, almost unanimously, ascribe the invention of the camel to a citizen of Amsterdam, who calls himself Meeuves Meindertsoon Bakker. “ Some make the year of the invention to have been 1688, and others 1690. Much has been said of the utility of this invention; but however beneficial it may be, we have reason to suppose that such heavy vessels as ships of war cannot be raised up, in so violent a manner, without sustaining injury. A sure proof of this is the well known circumstance mentioned by Muschenbroek (*Introductio ad Philosoph. Natur.*), that the ports of a ship which had been raised by the camel could not afterwards be shut closely.”

CAMELEON, one of the constellations of the southern hemisphere, near the south pole, and invisible in our latitude. There are 10 stars marked in this constellation in Sharp's catalogue.

CAMELOPARDALUS, a new constellation of the northern hemisphere, formed by Hevelius, consisting of 32 stars, first observed by him. It is situated between Cepheus, Cassiopeia, Perseus, the Two Bears, and Draco; and it contains 58 stars in the British catalogue.

CAMELLIA, in botany (see *Encycl.*), is a plant which the Chinese call *Cha-wba*, or flower of tea, on account of the resemblance of the one to the other, and because.

Camel
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Camellia.

Campbell. because its petals are sometimes mixed among the teas to increase their fragrance. Sir George Staunton, who calls it *Camellia Sefanqua*, saw it flourishing on the sides and very high tops of mountains, where the soil consisted of little more than fragments of stone, crumbled into a sort of coarse earth by the joint action of the sun and rain. It yields, he says, a nut, from which is expressed an esculent oil, equal to the best which comes from Florence. On this account, it is cultivated in vast abundance; and is particularly valuable from the facility of its culture in situations fit for little else.

CAMPBELL (George, D. D.), so justly admired for his metaphysical acuteness and various erudition, was, in 1719, born at Aberdeen, where his father, the reverend Colin Campbell, was one of the ministers of the established church. He was educated in his native city; and, after passing through the usual course of academical learning, he studied divinity under the Rev. J. Chalmers, professor of divinity in Marischal College.— He was, in 1749, an unsuccessful candidate for the church of Fordown, though his competitor Mr Forbes was a man of very slender abilities, and supposed to be attached to the constitution and liturgy of the church of England. It might indeed be that attachment which contributed principally to procure him the living in preference to Mr Campbell.

The living of Fordown is in the gift of the crown; and it has generally been a rule with his majesty's ministers, to give such livings, when they become vacant, to those candidates who are favoured by the majority of land-owners in the parish. At the era of 1749, the land-owners in some of the northern and middle counties of Scotland were more generally attached to the constitution of the church of England than to that of their own establishment; and such was certainly the case in the parish of Fordown.

But whatever was the cause of Mr Campbell's failure, he failed by a very small number, and was not long without an establishment. In 1750, he was presented, by Sir Thomas Burnet of Leys, to the living of Bancharry Ternan, on the Dee, about twenty miles west from Aberdeen. From this he was translated, or, as the Scotch ecclesiastical phrase is, *transported* to Aberdeen in 1756, and nominated one of the city ministers, in the room of Mr John Bisset deceased, a puritan of the old school, whose strictness and peculiarities are yet remembered by many in that place.

In 1759, on the decease of principal Pollock, he was chosen principal of the Marischal college, and succeeded to the divinity chair in 1771, on Dr Alexander Gerard being translated to the professorship of divinity in King's college. Before his settling in Aberdeen, he married Miss Grace Farquharson, daughter of Mr Farquharson of Whitehouse, by whom he had no issue. This amiable woman died about a year before him. They were an eminent pattern of conjugal affection.

From this time he enjoyed a remarkable share of good health and spirits. He had, all his life, a rooted aversion to medicine. He got the better of every ailment by a total and rigorous abstinence from all kind of sustenance whatever; and it was not till he was attacked by an alarming illness, about two years before his death, that he was persuaded by his friends to call in medical aid. What nature could do, she had all along performed well; but her day was over, and something of art be-

came necessary. Then, for the first time, he owned the utility of medical men, and declared his recantation of the very mean opinion he had formerly entertained of them and their art. A few months before his death, he resigned his offices of principal, professor of divinity, and one of the city ministers, and was in all succeeded by Dr W. L. Brown, late of Utrecht, a man of distinguished abilities. Dr Campbell retained all his faculties entire to the last, and died on the 6th of April 1796, in the 77th year of his age. His character has been so justly drawn by his successor, that we shall give it to our readers in his words, adding only a circumstance or two, which we have reason to think will contribute to endear his memory to every liberal and enlightened mind.

“ Dr Campbell, as a public teacher, was long admired for the clearness and copiousness with which he illustrated the great doctrines and precepts of religion, and the strength and energy with which he enforced them. Intimately persuaded of the truth and infinite consequence of what revelation teaches, he was strongly desirous of carrying the same conviction to the minds of his hearers, and delivered his discourses with that zeal which flows from strong impressions, and that power of persuasion which is the result of sincerity of heart, combined with clearness of understanding. He was satisfied, that the more the pure dictates of the gospel were studied, the more they would approve themselves to the mind, and bring forth, in the affection and conduct, all the peaceable fruits of righteousness. The unadulterated dictates of Christianity, he was, therefore, only studious to recommend and inculcate, and knew perfectly to discriminate them from the inventions and traditions of men. His chief study ever was, to direct belief to the great objects of practice; and, without these, he viewed the most orthodox profession as “ a sounding brass, and a tinkling cymbal.” But, besides the character of a preacher of righteousness, he had also that of a teacher of the science of divinity to sustain. How admirably he discharged this duty, and with what effect he conveyed the soundest and most profitable instruction to the minds of his scholars, let those declare who are now in various congregations of this country, communicating to their fellow Christians the fruits of their studies under so able and judicious a teacher. Discarding all attachment to human systems, merely considered as such, he tied his faith to the Word of God alone, possessed the happiest talent in investigating its meaning, and communicated to his hearers the result of his own inquiries, with a precision and perspicuity which brought light out of obscurity, and rendered clear and simple what appeared intricate and perplexed. He exposed, without reserve, the corruptions which ignorance, craft, and hypocrisy, had introduced into religion, and applied his talent for ridicule to the best of all purposes, to hold up to contempt the absurdities with which the purest and sublimest truths had been loaded.

“ Placed at the head of a public seminary of learning, he felt all the importance of such a situation, and uniformly directed his influence to public utility. His enlarged and enlightened mind justly appreciated the extensive consequence of the education of youth. He anticipated all the effects resulting to the great community of mankind, from numbers of young men issuing,

Campbell.

Campbell. in regular succession, from the university over which he presided, and occupying the different departments of social life.

“ His benevolent heart delighted to represent to itself the students under his direction usefully and honourably discharging the respective duties of their different professions; and some of them, perhaps, filling the most distinguished stations of civil society. With these prospects before him, he constantly directed his public conduct to their attainment. He never suffered his judgment to be warped by prejudice or partiality, or his heart to be seduced by passion or private interest. Those mean and ignoble motives by which many are actuated in the discharge of important trusts, approached not his mind. A certain honourable pride, if pride it may be called, diffused an uniform dignity over the whole of his behaviour. He felt the man degraded by the perversion of public character. His understanding also clearly shewed him even personal advantage attached to such principles and practice, as he adopted from a sense of obligation, and those elevated conceptions of real worth which were so congenial to his soul. He saw, he experienced, esteem, respect, and influence, following in the train of integrity and beneficence; but contempt, disgrace, aversion, and complete insignificance, closely linked to corruption and selfishness. Little minds are seduced and overpowered by selfish considerations, because they have not the capacity to look beyond the present advantage, and to extend to the misery that stands on the other side of it. The same circumstance that betrays the perversity of their hearts, also evinces the weakness of their judgments.

“ His reputation as a writer is as extensive as the present intercourse of letters; not confined to his own country, but spread through every civilized nation. In his literary pursuits, he aimed not, as is very often the case, with men of distinguished literary abilities, merely at establishing his own celebrity, or increasing his fortune; but had chiefly at heart the defence of the great cause of Religion, or the elucidation of her dictates.

“ At an early period he entered the lists as a champion for Christianity against one of its acutest opponents. He not only triumphantly refuted his arguments, but even conciliated his respect by the handsome and dexterous manner in which his defence was conducted. While he refuted the infidel, he spared the man, and exhibited the uncommon spectacle of a polemical writer possessing all the moderation of a Christian. But while he defended Christianity against its enemies, he was desirous of contributing his endeavours to increase, among its professors, the knowledge of the sacred writings. Accordingly, in the latter part of his life, he favoured the world with a work, the fruit of copious erudition, of unwearied application, for almost thirty years, and of a clear and comprehensive judgment. We have only to regret, that the other writings of the New Testament have not been elucidated by the same pen that translated the Gospels. Nor were his literary merits confined to theology, and the studies more immediately connected with it. Philosophy, and the fine arts, are also indebted to his genius and labours; and in him the polite scholar was eminently joined to the deep and liberal divine.

“ Political principles will always be much affected by general character. This was also the case with Dr
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Campbell. In politics, he maintained that moderation which is the surest criterion of truth and rectitude, and was equally distant from those extremes into which men are so apt to run on great political questions. He cherished that patriotism which consists in wishing, and endeavouring to promote the greatest happiness of his country, and is always subordinate to universal benevolence. Firmly attached to the British constitution, he was animated with that genuine love of liberty which it inspires and invigorates. He was equally averse to despotism and to popular anarchy; the two evils into which political parties are so frequently hurried, to the destruction of all that is valuable in government. Party-spirit, of whatever description, he considered as having an unhappy tendency to pervert, to the most pernicious purposes, the best principles of the human mind, and to clothe the most iniquitous actions with the most specious appearances. Although tenacious of those sentiments, whether in religion or politics, which he was convinced to be rational and just, he never suffered mere difference of opinion to impair his good-will, to obstruct his good offices, or to cloud the cheerfulness of conversation. His own conversation was enlivened by a vein of the most agreeable pleasantry.”

So far was he from being influenced by jealousy, or any portion of that corporation-spirit which sometimes incites men of undoubted abilities to detract from the merit of every writer who fills not a station as conspicuous as their own, that he was loud in his praises of those, whom men of meaner minds would have looked upon with disgust, as upon presumptuous rivals. This generosity was fully experienced by the writer of the article *MIRACLE*, in the *Encyclopædia Britannica*, who, though he had presumed to treat the subject differently from Dr Campbell, received from him such a testimony of approbation of what he had done, as he will hardly look for from any other man in similar circumstances.

Among his other qualities, which so much endeared him to all who had the honour of his acquaintance, Dr Campbell possessed an uncommon facility of passing from the gravest to the most airy subjects, and from the liveliest to the gravest, without degrading the one or diminishing the pleasure of the other. The infirmities of age abated not the cheerfulness of his temper, nor did even the persuasion of approaching dissolution impair his serenity.

We cannot conclude this short sketch better than with a list of his works, in the order in which they were published. In 1752, he published a Sermon, preached before the Synod of Aberdeen.

1761. A Dissertation on Miracles, against Mr Hume. This treatise is well known to the learned world. He obtained, and deservedly obtained, a very high reputation, not only from the able manner in which he handled the subject, but from the liberal style in which he addressed his antagonist. It was speedily translated into French, German, and Dutch.

1771. A Sermon before the Society for Propagating Christian Knowledge, Edinburgh.

_____ before the Synod of Aberdeen.
1776. The Philosophy of Rhetoric, 2 vols 8vo. A work which discovers a clearness of discernment, and accuracy of observation, which justly entitled him to be ranked among the most judicious critics. He entered on this inquiry as early as 1750, when a part of the
U
work

Camphor. work was composed. The laws of elegant composition and criticism are laid down with great perspicuity: but the most valuable part of the work is undoubtedly the *theory of evidence*, to which we know nothing superior, perhaps nothing equal, on the subject, in our own or any other language. His philosophy, in general, is the philosophy of Dr Reid; and where he differs from that acute reasoner respecting *abstraction*, and some other objects of metaphysical disquisition, we think it impossible to refuse him the pre-eminence in every thing but style.

1777. A Sermon on the King's Fast-day, on Allegiance, first printed in 4to, and afterwards, at the expence of government, six thousand copies were printed in 12mo, enlarged with notes, and sent to America, when the unhappy struggle had, however, put on appearances which prevented the effect hoped for from this sermon.

1780. An Address to the People of Scotland on the Alarms which have been raised by what is called the Popish Bill. This is a powerful dissuasive from bigotry, and every species of religious persecution.

1793. His *Magnum Opus*. The translation of the Gospels, with Preliminary Dissertations, 2 vols 4to.

1800. Lectures on Ecclesiastical History, a posthumous work, in 2 vols 8vo; which, in the opinion of most people, should have been suppressed.

CAMPBOR, or **CAMPHIRE**, (see *Encycl.*), is, in China, obtained by boiling the branches, twigs, and leaves, of the *Laurus-Camphora* in water, upon the surface of which it is found swimming in the form of an oil, or adhering, in a glutinous form, to a wooden rod, with which the boiling matter is constantly stirred. The glutinous mass is then mixed with clay and lime, and put into an earthen vessel, with another of the same size properly luted over it; the lower vessel being placed over a slow fire, the camphor gradually sublimes through the clay and lime, and adheres to the sides of the upper vessel, forming a cake of a shape corresponding to the cavity which received it. It is, however, less pure and much weaker than what is discovered in a solid state among the fibres of the trunk, as turpentine is found in different sorts of pines. In the great, but ill-peopled, island of Borneo, and also in Japan, the camphor tree is felled for the sole purpose of finding this costly drug in substance among the splinters of the trunk, in the same manner as other trees are felled in Louisiana merely for collecting the fruit they bear upon their summits. The Borneo, or Japan camphor, is pure, and so very strong, as readily to communicate much of its odour and its virtues to other inspissated oils, which thus pass for real camphor; and this adulterated drug is sold by Chinese artists at a vastly lower price than they gave themselves for the genuine substance from Borneo or Japan.

Sir George Staunton, from whom we have this account, does not inform us whether the camphor-tree of China, if felled and torn into splinters, would not produce as large quantities of the drug, and equally pure, as the trees of Borneo and Japan; but he assures us, that in China it is never so torn, being there a large and valuable timber-tree. "It is used (says he) in the best buildings of every kind, as well as for masts of vessels, and bears too high a price to allow of any part, except the branches, being cut up for the sake of the drug."

CANALS OF COMMUNICATION may be of such advantage in a commercial or agricultural country, that every attempt to render them more convenient, and less expensive in the construction, is intitled to public notice. In the *Encyclopædia*, an account, sufficiently perspicuous, is given of the common canals with locks; but in many cases it is very difficult to provide a sufficient quantity of water for the consumption of a canal where many boats are to pass. Different attempts have therefore been made, by ingenious men, to save water in the passing of boats or lighters from one lock of a canal to another; and, among these, perhaps none is more deserving of public favour than the following, by the late Mr James Playfair of Ruffel-street, architect. We shall state his invention in his own words.

"The nature and principle of this manner of saving water consist in letting the water which has served to raise or fall a boat or barge from the lock, pass into reservoirs or cisterns, whose apertures of communication with the lock are upon different levels, and which may be placed or constructed at the side or sides of the lock with which they communicate, or in any other contiguous situation that circumstances may render eligible; which apertures may be opened or shut at pleasure, so that the water may pass from the lock to each reservoir of the canal, or from each reservoir to the lock, in the following manner: The water which fills the lock, when a boat is to ascend or descend, instead of being passed immediately into the lower part of the canal, is let pass into these cisterns or reservoirs, upon different levels; then, their communications with the lock being shut, they remain full until another vessel is wanted to pass; then, again, the cisterns are emptied into the lock, which is thereby nearly filled, so that only the remainder which is not filled is supplied from the higher part of the canal. Each of these cisterns must have a surface not less than that of the lock, and must contain half as much water as is meant to be expended for the passing of each vessel. The cistern the most elevated is placed twice its own depth (measuring by the aperture, or communicating opening of the cisterns) under the level of the water in the higher part of the canal. The second cistern is placed once its own depth under the first, and so on are the others to the lowest; which last is placed once its own depth above the level of the water in the lower part of the canal. The apertures of the intermediate cisterns, whatever their number may be, must all be equally divided into different levels; the surface of the water in the one being always on the level of the bottom of the aperture of the cistern which is immediately above. As an example of the manner and rule for constructing these cisterns, suppose that a lock is to be constructed twelve feet deep, that is, that the vessel may ascend or descend twelve feet in passing. Suppose the lock sixty feet long and six feet wide, the quantity of water required to fill the lock, and to pass a boat, is 4320 cubic feet; and suppose that, in calculating the quantity of water that can be procured for supplying the canal, after allowing for waste, it is found (according to the number of boats that may be expected to pass) that there will not be above 800 cubic feet for each; then it will be necessary to save five-sixths of the whole quantity that in the common case would be necessary: to do which ten cisterns must be made (the mode of placing which is ex-

pressed in the drawing, fig. 1. Plate VII.), each of which must be one foot deep, or deeper at pleasure, and each must have a surface of 360 feet square, equal to the surface of the lock. The bottom of the aperture of the lowest cistern must be placed one foot above the level of the water in the lower part of the canal, or eleven feet under the level of the high water; the second cistern must be two feet above the level of the low water; the third three feet, and so on of the others; the bottom of the tenth, or uppermost cistern, being ten feet above the low water, and two feet lower than the high water; and, as each cistern must be twelve inches in depth, the surface of the water in the higher cistern will be one foot under the level of the water in the upper part of the canal. The cisterns being thus constructed, when the lock is full, and the boat to be let down, the communications between the lock and the cisterns, which until then have all been shut, are to be opened in the following manner: first, the communication with the higher cistern is opened, which, being at bottom two feet under the level of the water in the lock, is filled to the depth of one foot, the water in the lock descending one foot also at the same time; that communication is then shut, and the communication between the lock and the second cistern is opened; one foot more of the water then passes into that cistern from the lock, and fills it; the opening is then shut: the same is done with the third, fourth, fifth, sixth, seventh, eighth, ninth, and tenth, cisterns, one by one, until they are all filled; and when the tenth, or lowermost cistern, is filled, there remains but two feet depth of water in the lock. The communication between the lock and the lower part of the canal is then opened, and the last two feet depth of water is emptied into the lower part of the canal. By this means, it is evident that, instead of twelve feet depth of water being let descend into the lower part of the canal, there is only two feet depth that descends, or one-sixth of the whole; therefore, instead of 4320 cubic feet being used, there are only 720 cubic feet used: the remainder of the water in the cisterns being used as follows: When another boat is to mount, the sluices being then shut, and the boat in the lock, the tenth or lowermost cistern is emptied into the lock, which it fills one foot; the communication being then shut, the next lowest cistern, or the ninth, is emptied into the lock, which is thereby filled another foot; and so, in like manner, all the other cisterns are emptied one after another, until the higher cistern being emptied, which fills the tenth foot of water in the lock, there remains but two feet of water to fill, which is done from the upper part of the canal by opening the higher sluice to pass the boat; by that means, the same quantity of water descends from the upper part of the canal into the lock, that in the other case descended from the lock into the lower part of the canal; so that, in both cases, the same quantity of water is saved, that is, five-sixths of what would be necessary were there no cisterns. Suppose again that, upon the same canal, and immediately after the twelve feet lock, it would be advantageous to construct one of eighteen feet; then, in order not to use any greater quantity of water, it will be necessary to have sixteen cisterns, upon different levels, communicating with the lock in the same manner. Should, again, a lock of only six feet be wanted, after that of eighteen, then it

will only be necessary to have four cisterns on different levels, and so of any other height of lock. The rule is this: For finding the number and size of the cisterns, each cistern being the same in superficies with the lock, its depth must be such as to contain one half the quantity of water meant to be used in the passing of one boat. The depth of the lock, divided by the depth necessary for such a cistern, will give, in all cases, the whole number of cisterns, and two more: deduct the number two, therefore, from the number which you find by dividing the depth of the lock by the depth of one cistern, and you have always the number of cisterns required; which are to be placed upon different levels, according to the rule already given. The above is the principle and manner of using the lock, for saving water in canals, and for enabling engineers to construct locks of different depths upon the same canal, without using more water for the deep locks than for the shallow ones. With regard to the manner of disposing the cisterns, the circumstances of the ground, the declivity, &c. will be the best guide for the engineer."

But supposing a sufficiency of water, or admitting that this method of Mr Playfair's of saving it, were defective, is adequate to his fondest expectations, still, in passing numerous locks, where the rise is considerable, the interruption is so great, that it has often been wished that an eligible method of lowering and elevating boats could be devised, without the assistance of water-locks. Though this is evidently at first view practicable, and several different modes of doing it have been suggested, some of which have actually been carried into effect, yet all of them have been found to be attended with such inconvenience as to render an improvement in this respect still necessary.

In China, where water-carriage is more generally practised than in any kingdom of Europe, boats are raised and lowered from one canal into another, by sliding them along an inclined plane: but the contrivances for effecting that purpose are so awkward, and such a number of hands are required, that it has in general been deemed inexpedient to resort to that mode of practice in Europe. Several devices, that discover considerable ingenuity, however, have been published, with a view to facilitate this operation; either by rendering the motion up the inclined plane more equable, or producing a power sufficient to move these great weights. But none of them have yet been so simple in their construction as could be wished, nor have they afforded satisfaction in practice. For the greater part of them, likewise, patents have been granted; so that whatever be their value, no engineer could avail himself of them without previously purchasing a licence from the patentee.

The following contrivance for this purpose is the invention of James Anderson, LL. D. whose knowledge of economics is well known, and of whose public spirit there cannot be a doubt. Instead of applying for a patent, to secure to himself the fruits of his ingenuity, he published, for the good of his countrymen in general, his device, in the View of the Agriculture of the County of Aberdeen, which he drew up for the consideration of the board of agriculture. He introduces it to public notice with justly observing, that it possesses at least the merit of simplicity, in as high a degree, per-

Canals. haps, as could be wished; and, "in the opinion (says he) of very good judges of matters of this sort, to whom the plan has been shewn, it has been deemed fully adequate to the purpose of raising and lowering boats of a moderate size, that is, of 20 tons, or downwards; and it is the opinion of most men with whom I have conversed, who are best acquainted with the inland navigations, that a boat of from 10 to 15 tons is better than those of a larger size. When several are wanted to be sent at once, they may be affixed to one another, as many as the towing-horse can conveniently draw. Were boats of this size adopted, and were all the boats on one canal to be of the same dimensions, it would prove a great convenience to a country in a state of beginning improvements; because the expence of such a boat would be so trifling, that every farmer could have one for himself, and might of course make use of it when he pleased by the aid of his own horse, without being obliged to have any dependence on the time that might suit the convenience of his neighbour; and if two or more boats were going from the same neighbourhood, one horse could serve the whole.

"You are to suppose that fig. 2. (Plate VII.) represents a bird's-eye view of this simple apparatus, as seen from above. A is supposed to be the upper reach of the canal, and B the lower reach, with the apparatus between the two. This consists of three divisions; the middle one, extending from C to D, is a solid piece of masonry, raised from a firm foundation below the level of the bottom of the second reach: this is again divided into five parts, viz. *ddd*, where the wall rises only to the height of the water in the upper reach, and *ee*, two pillars, raised high enough to support the pivots of a wheel or pulley *g*, placed in the position there marked.

"The second division *b* consists of a wooden coffer, of the same depth nearly as the water in the upper reach, and of a size exactly fitted to contain one of the boats. This communicates directly with the upper reach, and being upon the same plane with it, and so connected with it as to be water-tight, it is evident, from inspection, that nothing can be more easy than to float a boat into this coffer from the upper reach; the part of the wheel that projects over it being at a sufficient height above it, so as to occasion no sort of interruption.

"Third division. At *i* is represented another coffer, precisely of the same dimensions with the first. But here two sluices, which were open in the former, and only represented by dotted lines, are supposed to be shut, so as to cut off all communication between the water in the canal and that in the coffer. As it was impossible to represent this part of the apparatus on so small a scale, for the sake of illustration it is represented more at large in fig. 5. where A, as before, represents the upper reach of the canal, and *b* one of the coffers. The sluice *k* goes into two cheeks of wood, joined to the masonry of the dam of the canal, so as to fit perfectly close; and the sluice *f* fits equally close into cheeks made in the side of the coffer for that purpose; between these two sluices is a small space *o*. The coffer, and this division *o*, are to be supposed full of water, and it will be easy to see that these sluices may be let down or drawn up at pleasure with much facility.

Canals. "Fig. 6. represents a perpendicular section of these parts in the same direction as in fig. 5. and in which the same letters represent the same parts.

"Things being thus arranged, you are to suppose the coffer *b* to be suspended, by means of a chain passed over the pulley, and balanced by a weight that is sufficient to counterpoise it, suspended at the opposite end of the chain. Suppose, then, that the counterpoise be made somewhat lighter than the coffer with its contents, and that the line *mn* (fig. 6.) represents a division between the solid sides of the dam of separation, which terminates the upper reach and the wooden coffer, which had been closed only by the pressure of its own weight (being pushed a very little from A towards B, beyond its precise perpendicular swing), and that the joining all round is covered with lifts of cloth put upon it for that purpose; it is evident that, so long as the coffer is suspended to this height, the joining must be water-tight; but no sooner is it lowered down a little than this joining opens, the water in the small division *o* is allowed to run out, and an entire separation is made between the fixed dam and this moveable coffer, which may be lowered down at pleasure without losing any part of the water it contained.

"Suppose the coffer now perfectly detached, turn to fig. 3. which represents a perpendicular section of this apparatus, in the direction of the dotted line *pp* (fig. 2.) In fig. 3. *b* represents an end view of the coffer, indicated by the same letter as in fig. 2. suspended by its chain, and now perfectly detached from all other objects, and balanced by a counterpoise *i*, which is another coffer exactly of the same size, as low down as the level of the lower reach. From inspection only, it is evident, that in proportion as the one of these weights rises, the other must descend. For the present, then, suppose that the coffer *b* is by some means rendered more weighty than *i*, it is plain it will descend while the other rises; and they will thus continue till *b* comes down to the level of the lower reach, and *i* rises to the level of the higher one.

"Fig. 4. represents a section in the direction AB (fig. 2.), in which the coffer *i* (seen in both situations) is supposed to have been gradually raised from the level of the lower reach B, to that of the higher A, where it now remains stationary; while the coffer *b* (which is concealed behind the masonry) has descended in the mean time to the level of the lower reach, where it closes by means of the juncture *rs*, fig. 6. (which juncture is covered with lifts of cloth, as before explained. at *mn*, and is of course become water-tight), when, by lifting the sluice *i*, and the corresponding sluice at the end of the canal, a perfect communication by water is established between them. If, then, instead of water only, this coffer had contained a boat, floated into it from the upper reach, and then lowered down, it is very plain that when these sluices were removed, after it had reached the level of the lower reach, that boat might have been floated out of the coffer with as much facility as it was let into it above. Here then we have a boat taken from the higher into the lower canal; and, by reversing this movement, it is very obvious that it might be, with equal ease, raised from the lower into the higher one. It now only remains that I should explain by what means the equilibrium between these

LARGE SNOUTED BOAR



Fig. 2.

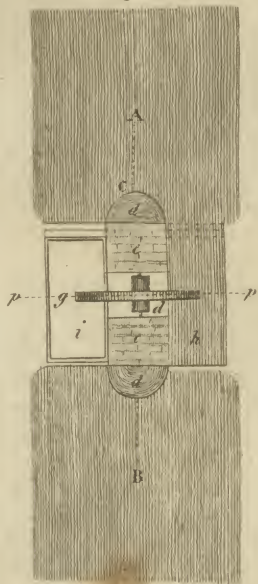


Fig. 3.

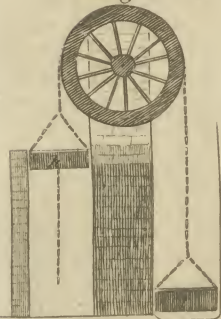


Fig. 6.

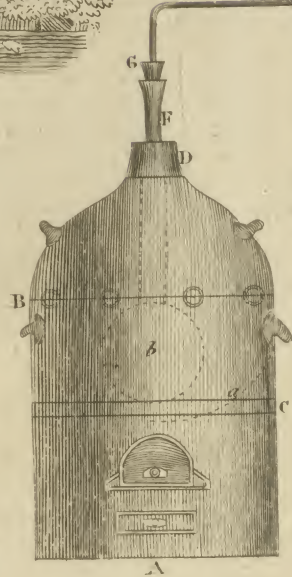
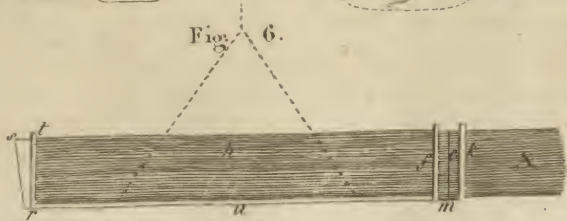
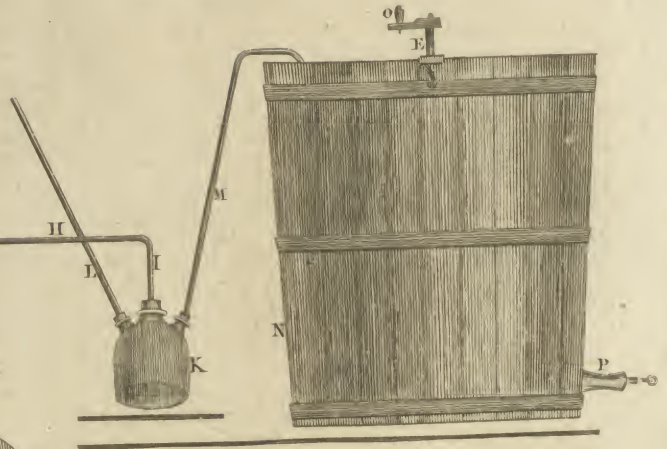


Fig. 4.



BLEACHING



CANALS

Fig. 1.

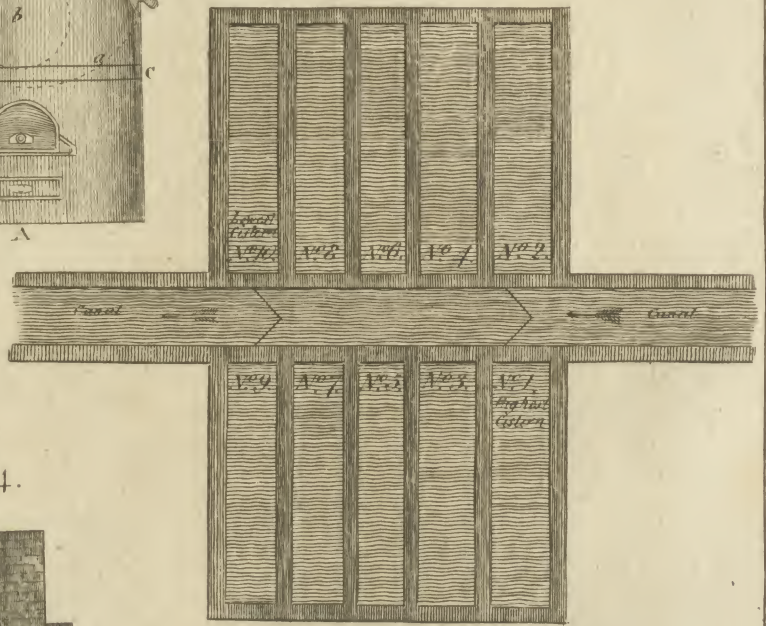
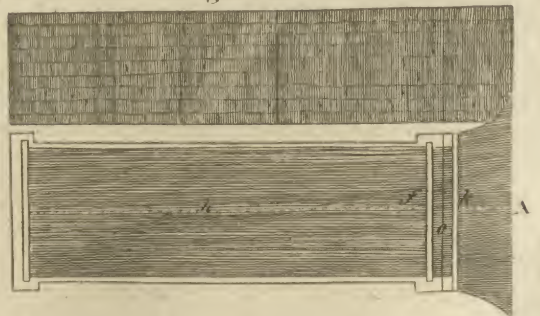
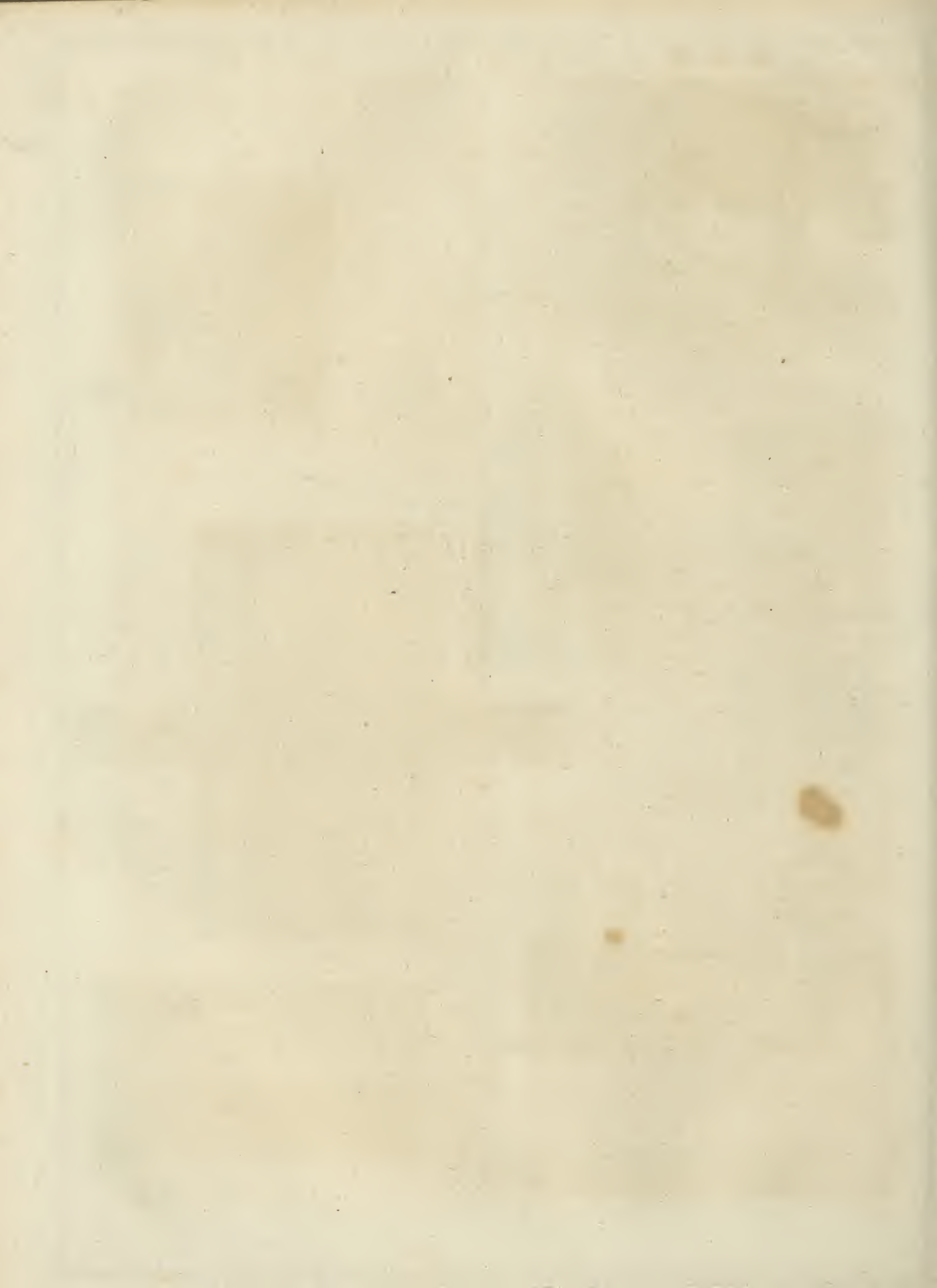


Fig. 5.





Canals. these counterbalancing weights can be destroyed at pleasure, and the motion of course produced.

“ It is very evident, that if the two corresponding coffers be precisely of the same dimensions, their weight will be exactly the same when they are both filled to the same depth of water. It is equally plain, that should a boat be floated into either or both of them, whatever its dimensions or weight may be, so that it can be contained afloat in the coffer, the weight of the coffer and its contents will continue precisely the same as when it was filled with water only: hence, then, supposing one boat is to be lowered, or one to be raised at a time, or supposing one to be raised and another lowered at the same time—they remain perfectly in equilibrium in either place, till it is your pleasure to destroy that equilibrium. Suppose, then, for the present, that both coffers are loaded with a boat in each, the double sluices both above and below closed; and suppose also that a stop-cock *u*, in the under edge of the side of the lower coffer (fig. 4. and 6.), is opened, some of the water which served to float the boat in the coffer will flow out of it, and consequently that coffer will become lighter than the higher one; the upper coffer will of course descend, while the other mounts upwards. When a gentle motion has been thus communicated, it may be prevented from accelerating, merely by turning the stop-cock so as to prevent the loss of more water, and thus one coffer will continue to ascend, and the other to descend, till they have assumed their stations respectively; when, in consequence of a stop below, and another above, they are rendered stationary at the level of the respective canals (A).

“ Precisely the same effect will be produced when the coffers are filled entirely with water.

“ It is unnecessary to add more to this explanation, except to observe that the space for the coffer to descend into must be deeper than the bottom of the lower canal, in order to allow a free descent for the coffer to the requisite depth; and of course it will be necessary to have a small conduit to allow the water to get out of it. Two or three inches free, below the bottom of the canal, is all that would be necessary.

“ Where the height is inconsiderable, there will be no occasion for providing any counterpoise for the chain, as that will give only a small addition to the weight of the undermost coffer, so as to make it preponderate, in circumstances where the two coffers would otherwise be in perfect equilibrium: but, where the height is considerable, there will be a necessity for providing such a counterpoise; as, without it, the chain, by becoming more weighty every foot it descended, would tend to destroy the equilibrium too much, and accelerate the motion to an inconvenient degree. To guard against this inconvenience, let a chain of the same weight, per foot, be appended at the bottom of each coffer, of such a length as to reach within a few yards of the ground where the coffer is at its greatest height (see fig. 3.); it will act with its whole weight upon the highest coffer while in this position; but, as that gradually descended, the chain would reach the ground, and, being there supported, its weight would be di-

minished in proportion to its descent; while the weight of the chain on the opposite side would be augmented in the same proportion, so as to counterpoise each other exactly, in every situation, until the uppermost chain was raised from the ground. After which it would increase its weight no more; and, of course, would then give the under coffer that preponderance which is necessary for preserving the machine steady. The under coffer, when it reached its lowest position, would touch the bottom on its edges, which would then support it, and keep every thing in the same position, till it was made lighter for the purpose of ascending.

“ What constitutes one particular excellence of the apparatus here proposed is, that it is not only unlimited as to the extent of the rise or depression of which it is susceptible (for it would not require the expenditure of one drop more water to lower it one hundred feet than one foot); but it would also be easy so to augment the number of pulleys at any one place as to admit of two, three, four, or any greater number of boats being lowered or elevated at the same time; so that let the succession of boats on such a canal be nearly as rapid as that of carriages upon a highway, none of them need be delayed one moment to wait an opportunity of passing: a thing that is totally impracticable where water-locks are employed; for the intercourse, on every canal constructed with water-locks, is necessarily limited to a certain degree, beyond which it is impossible to force it.

“ For example: suppose a hundred boats are following each other, in such a rapid succession as to be only half a minute behind each other: By the apparatus here proposed, they would all be elevated precisely as they came; in the other, let it be supposed that the lock is so well constructed as that it takes no more than five minutes to close and open it; that is, ten minutes in the whole to each boat (for the lock, being once filled, must be again emptied before it can receive another in the same direction): at this rate, six boats only could be passed in an hour, and of course it would take sixteen hours and forty minutes to pass the whole hundred; and as the last boat would reach the lock in the space of fifty minutes after the first, it would be detained fifteen hours and fifty minutes before its turn would come to be raised. This is an immense detention; but if a succession of boats, at the same rate, were to follow continually, they never could pass at all. In short, in a canal constructed with water-locks, not more than six boats, on an average, can be passed in an hour, so that beyond that extent all commerce must be stopped; but, of the plan here proposed, sixty, or six hundred, might be passed in an hour if necessary, so as to occasion no sort of interruption whatever. These are advantages of a very important nature, and ought not to be overlooked in a commercial country.

“ This apparatus might be employed for innumerable other uses as a moving power, which it would be foreign to our present purpose here to specify. Nor does its power admit of any limitation, but that of the strength of the chain, and of the coffers which are to support the weights. All the other parts admit of being,

(A) “ It does not seem necessary to adopt any other contrivance than the above for regulating the motions; but if it should be found necessary, it would be easy to put a ratch-wheel on the same axle.”

Canary-Bird.

being made so immovably firm as to be capable of supporting almost any assignable weight.

“ I will not enlarge on the benefits that may be derived from this very simple apparatus: its cheapness, when compared with any other mode of raising and lowering vessels that has ever yet been practised, is very obvious; the waste of water it would occasion is next to nothing; and when it is considered that a boat might be raised or lowered fifty feet nearly with the same ease as five, it is evident that the interruptions which arise from frequent locks would be avoided, and an immense saving be made in the original expence of the canal, and in the annual repairs.

“ It is also evident that an apparatus, on the same principle, might be easily applied for raising coals or metals from a great depth in mines, wherever a very small stream of water could be commanded, and where the mine was level-free.”

CANARY-BIRD, of which a description is given in the Encyclopædia, was not known in Europe till towards the end of the 15th century. Even in 1555, Bellon, who about that time described all the birds then known, does not so much as mention it. When it was first brought from the Canary Islands, it was so dear that it could be purchased only by people of fortune, who were often imposed upon. It was called the *sugar-bird*, because it was said to be fond of the sugarcane; and could eat sugar in great abundance. This is rather a singular circumstance, sugar being to many fowls a poison. Experiments have shewn that a pigeon, to which four drams of sugar was given, died in four hours; and that a duck, which had swallowed five drams, did not live seven hours.

In the middle of the last century canary-birds began to be bred in Europe; and to this the following circumstance, related by Olina, seems to have given occasion: “ A vessel which, among other commodities, was carrying a number of canary birds to Leghorn, was wrecked on the coast of Italy; and these birds being thus set at liberty, flew to the nearest land, which was the island of Elba, where they found the climate so favourable, that they multiplied, and perhaps would have become domesticated, had they not been caught in snares; for it appears that the breed of them there has been long destroyed. Olina says that the breed soon degenerated; but it is probable that by much the greater part of these canary-birds were males, which coupling with birds of the island, produced mules, such as are described by Gesner and other naturalists.”

“ Various treatises have been published in different languages, on the manner of breeding these birds, and many people have made it a trade, by which they have acquired considerable gain. It does no discredit to the industry of the Tyrolians, that they have carried it to the greatest extent. At Ymsl there is a company, who, after the breeding season is over, send out persons to different parts of Germany and Switzerland to purchase birds from those who breed them. Each person brings with him commonly from three to four hundred, which are afterwards carried for sale, not only through every part of Germany, but also to England, Russia, and even Constantinople. About sixteen hundred are brought every year to England; where the dealers in them, notwithstanding the considerable expence they are at, and after carrying them about on their backs, perhaps a

hundred miles, sell them for five shillings a piece. This trade, hitherto neglected, is now carried on in Schwartzwalde; and at present there is a citizen at Gottingen who takes with him every year to England several canary-birds and bullfinches (*loxia pyrrhula*), with the produce of which he purchases such small wares as he has occasion for.”—*Professor Beckmann's History of Inventions and Discoveries.*

CANARY-Seed. See PHALARIS, *Encycl.*—Professor Beckmann doubts whether the plant which bears the canary-seed be the *phalaris* of the ancients, because that name seems to have been given by Pliny to more than one species of grass. He thinks it very probable, however, that the plant, which the modern botanists call *phalaris*, was first brought from the Canary Islands to Spain, where it began to be cultivated, as well as in the south of France, as soon as canary-birds came into general esteem. At present it is cultivated in various places, and forms no inconsiderable branch of trade, particularly in the island of Sicily, where it is called *Scagliuola* or *Scagliola*. Were it not that the grains are not easily freed from the husks, this plant might be cultivated for the food of man, for its seeds yield a good kind of meal. The *phalaris* has by several writers been confounded with *argol* or the *lichen rocolla* of Linnæus; but they are very different plants. See *LICHEN Rocolle* in this Supplement.

CANDLE, a thing so universally known as to need no particular description. Its use, however, is so great, that every information tending to its improvement must, we should think, be acceptable to our readers. Of the common method of making candles, whether of wax or of tallow, a sufficient account has been given in the Encyclopædia; but candles of every kind are far from being yet brought to that degree of perfection of which they seem susceptible. Thus, for example, the light of a candle, which is so exceedingly brilliant when first snuffed, is very speedily diminished to one half, and is usually not more than one-fifth or one-sixth, before the uneasiness of the eye induces us to snuff it. Hence it follows, that if candles could be made so as not to require snuffing, the average quantity of light afforded by the same quantity of combustible matter would be more than doubled. It may likewise be worthy of inquiry, since the cost and duration of candles are easily ascertainable, whether more or less light is obtained at the same expence during a given time, by burning a number of small candles instead of one of greater thickness.

To determine this last point, a method must be found of measuring the comparative intensities of light, for which see PHOTOMETER in this Supplement. With respect to the desideratum first mentioned, we have some very ingenious observations and well-contrived experiments by Mr Nicholson, in the second number of his valuable Journal, which we shall here insert nearly in the words of their author.

In every process of combustion the free access of air is of the utmost consequence. When a candle has a very slender wick, the flame is small and of a brilliant white colour; if the wick be large, the combustion is less perfect, and the flame brown; and a wick still larger, not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatized matter, which does not become ignited till it has ascended towards the point. When the wick is either

Canary-Seed, Candle.

Candle. either very large or very long, part of this matter escapes combustion, and shews itself in the form of coal or smoke. The same things take place in the burning of a lamp; but when the wick of a lamp is once adjusted as to its length, the flame continues nearly in the same state for a much longer time than the flame of a candle.

“ Upon comparing a candle with a lamp (says Mr Nicholson), two very remarkable particulars are immediately seen. In the first place, the tallow itself, which remains in the unused state, affords a cup or cavity to hold that portion of melted tallow which is ready to flow into the lighted part of the wick. In the second place, the combustion, instead of being confined, as in the lamp, to a certain determinate portion of the fibrous matter, is carried, by a slow succession, through the whole length. Hence arises the greater necessity for frequent snuffing the candle; and hence also the station of the freezing point of the fat oil becomes of great consequence. For it has been shewn, that the brilliancy of the flame depends very much on the diameter of the wick being as small as possible; and this requisite will be most attainable in candles formed of a material that requires a higher degree of heat to fuse it. The wick of a tallow candle must be made thicker in proportion to the greater fusibility of the material, which would otherwise melt the sides of the cup, and run over in streams. The flame will therefore be yellow, smoky, and obscure, excepting for a short time immediately after snuffing. Tallow melts at the 92d degree of Fahrenheit’s thermometer; spermaceti at the 133d degree; the fatty matter formed of flesh, after long immersion in water, melts at 127 degrees; the *seal* of the Chinese at 145 degrees; bees-wax at 142 degrees; and bleached wax at 155 degrees. Two of these materials are well known in the fabrication of candles. Wax in particular does not afford so brilliant a flame as tallow; but, on account of its less fusibility, the wick can be made smaller, which not only affords the advantage of a clear perfect flame, but from its flexibility it is disposed to turn on one side, and come in contact with the external air, which completely burns the extremity of the wick to white ashes, and thus performs the office of snuffing. We see therefore that the important object to society of rendering tallow candles equal to those of wax, does not at all depend on the combustibility of the respective materials, but upon a mechanical advantage in the cup, which is afforded by the inferior degree of fusibility in the wax; and that, to obtain this valuable object, one of the following effects must be produced: Either the tallow must be burned in a lamp, to avoid the gradual progression of the flame along the wick; or some means must be devised to enable the candle to snuff itself, as the wax candle does; or, lastly, the tallow itself must be rendered less fusible by some chemical process. I have no great reason to boast of success in the endeavour to effect these; but my hope is, that the facts and observations here presented may considerably abridge the labour of others in the same pursuit.

“ The makers of thermometers and other small articles with the blow-pipe and lamp, give the preference to tallow instead of oil, because its combustion is more complete, and does not blacken the glass. In this operation the heat of the lamp melts the tallow which is

occasionally brought into its vicinity by the workman. But for the usual purposes of illumination, it cannot be supposed that a person can attend to supply the combustible matter. Considerable difficulties arise in the project for affording this gradual supply as it may be wanted. A cylindrical piece of tallow was inserted into a metallic tube, the upper aperture of which was partly closed by a ring, and the central part occupied by a metallic piece nearly resembling that part of the common lamp which carries the wick. In this apparatus the piece last described was intended to answer the same purpose, and was provided with a short wick. The cylinder of tallow was supported beneath in such a manner that the metallic tube and other part of this lamp were left to rest with their whole weight upon the tallow at the ring or contraction of the upper aperture. In this situation the lamp was lighted. It burned for some time with a very bright clear flame, which, when compared with that of a candle, possessed the advantage of uniform intensity, and was much superior to the ordinary flame of a lamp in its colour, and the perfect absence of smell. After some minutes it began to decay, and very soon afterwards went out. Upon examination, it was found that the metallic piece which carried the wick had fused a sufficient quantity of tallow for the supply during the combustion; that part of this tallow had flowed beneath the ring, and to other remote parts of the apparatus, beyond the influence of the flame; in consequence of which, the tube and the cylinder of tallow were fastened together, and the expected progression of supply prevented. It seems probable that, in every lamp for burning consistent oils, the material ought to be so disposed that it may descend to the flame upon the principle of the fountain reservoir. I shall not here state the obstacles which present themselves in the prospect of this construction, but shall dismiss the subject by remarking, that a contrivance of this nature would be of the greatest public utility.

“ The wick of a candle being surrounded by the flame, is nearly in the situation of a body exposed to destructive distillation in a close vessel. After losing its volatile products, the carbonaceous residue retains its figure, until, by the descent of the flame, the external air can have access to its upper extremity. But, in this case, the requisite combustion, which might snuff it, is not effected: for the portion of oil emitted by the long wick is not only too large to be perfectly burned, but also carries off much of the heat of the flame while it assumes the elastic state. By this diminished combustion and increased efflux of half-decomposed oil, a portion of coal or soot is deposited on the upper part of the wick, which gradually accumulates, and at length assumes the appearance of a fungus. The candle does not then give more than one-tenth of the light emitted in its best state. Hence it is that a candle of tallow cannot spontaneously snuff itself. It was not probable that the addition of a substance containing vital air or oxygen would supply that principle at the precise period of time required; but as experiment is the test of every probability of this nature, I soaked a wick of cotton in a solution of nitre, then dried it, and made a candle. When this came to be lighted, nothing remarkable happened for a short time; at the expiration of which a decrepitation followed at the lower extremity of the flame, which completely divided the wick

where

Candle.

Candle.

where the blackened part commences. The whole of the matter in combustion therefore fell off, and the candle was of course instantly extinguished. Whether this would have happened in all proportions of the salt or constructions of the candle, I did not try, because the smell of azot was sufficiently strong and unpleasant to forbid the use of nitre in the pursuit. From various considerations, I am disposed to think that the spontaneous snuffing of candles made of tallow, or other fusible materials, will scarcely be effected but by the discovery of some material for the wick which shall be voluminous enough to absorb the tallow, and at the same time sufficiently flexible to bend on one side.

"The most promising speculation respecting this most useful article, seems to direct itself to the cup which contains the melted tallow. The imperfection of this part has already been noticed, namely, that it breaks down by fusion, and suffers its fluid contents to escape. The Chinese have a kind of candle about half an inch in diameter, which, in the harbour of Canton, is called a *lobchock*; but whether the name be Chinese, or the corruption of some European word, I am ignorant. The wick is of cotton, wrapped round a small stick or match of the bamboo cane. The body of the candle is white tallow; but the external part, to the thickness of perhaps one thirtieth of an inch, consists of a waxy matter coloured red. This covering gives a considerable degree of solidity to the candle, and prevents its guttering, because less fusible than the tallow itself. I did not observe that the stick in the middle was either advantageous or the contrary; and as I now write from the recollection of this object at so remote a period as 25 years ago, I can only conjecture that it might be of advantage in throwing up a less quantity of oil into the flame than would have been conveyed by a wick of cotton sufficiently stout to have occupied its place unsupported in the axis of the candle.

"Many years ago I made a candle in imitation of the lobchock. The expedient to which I had recourse consisted in adapting the wick in the usual pewter mould: wax was then poured in, and immediately afterwards poured out: the film of wax which adhered to the inner surface of the mould soon became cool, and the candle was completed by filling the mould with tallow. When it was drawn out, it was found to be cracked longitudinally on its surface, which I attributed to the contraction of the wax, by cooling, being greater than that of the tallow. At present I think it equally probable that the cracking might have been occasioned by too sudden cooling of the wax before the tallow was poured in; but other avocations prevented the experiments from being varied and repeated. It is probable that the Chinese external coating may not be formed of pure hard bleached wax.

"But the most decisive remedy for the imperfection of this cheapest, and in other respects best, material for candles, would undoubtedly be to diminish its fusibility. Various substances may be combined with tallow, either in the direct or indirect method. In the latter way, by the decomposition of soap, a number of experiments were made by Berthollet, of which an account is inserted in the memoirs of the Academy at Paris for the year 1780, and copied into the 26th volume of the *Journal de Physique*. None of these point directly to the present object; besides which, it is probable that

the soap made use of by that eminent chemist was formed not of tallow, but oil. I am not aware of any regular series of experiments concerning the mutual action of fat oils and other chemical agents, more especially such as may be directed to this important object of diminishing its solubility; for which reason I shall mention a few experiments made with this view.

"1. Tallow was melted in a small silver vessel. Solid tallow sinks in the fluid, and dissolves without any remarkable appearance. 2. Gum sandarach in tears was not dissolved, but emitted bubbles, swelled up, became brown, emitted fumes, and became crisp or friable. No solution nor improvement of the tallow. 3. Shell-lac swelled up with bubbles, and was more perfectly fused than the gum sandarach in the former experiment. When the tallow was poured off, it was thought to congeal rather more speedily. The lac did not appear to be altered. 4. Benzoin bubbled without much swelling, was fused, and emitted fumes of an agreeable smell, though not resembling the flowers of benzoin. A slight or partial solution seemed to take place. The benzoin was softer and of a darker colour than before, and the tallow less consistent. 5. Common resin unites very readily with melted tallow, and forms a more fusible compound than the tallow itself. 6. Camphor melts easily in tallow, without altering its appearance. When the tallow is near boiling, camphoric fumes fly off. The compound appeared more fusible than tallow. 7. The acid or flowers of benzoin dissolves in great quantities without any ebullition or commotion. Much smoke arises from the compound, which does not smell like the acid of benzoin. Tallow alone does not fume at a low heat, though it emits a smell something like that of oil olive. When the proportion of the acid was considerable, small needled crystals appeared as the temperature diminished. The appearances of separation are different according to the quantity of acid. The compound has the hardness and consistence of firm soap, and is partially transparent. 8. Vitriolated tartar, nitre, white sugar, cream of tartar, crystallized borax, and the salt sold in the markets under the name of salt of lemons, but which is supposed to be the essential salt of sorrel, or vegetable alkali superaturated with acid of sugar, were respectively tried without any obvious mutual action or change of properties in the tallow. 9. Calcined magnesia rendered tallow opaque and turbid, but did not seem to dissolve. Its effect resembled that of lime.

"It is proposed to try the oxygenated acetous acid, or radical vinegar; the acid of ants, of sugar, of borax, of galls, the tanning principle, the serous and gelatinous animal matter, the fecula of vegetables, vegetable gluten, bird-lime, and other principles, either by direct or indirect application. The object, in a commercial point of view, is intitled to an extensive and assiduous investigation. Chemists in general suppose the hardness or less fusibility of wax to arise from oxygen; and to this object it may perhaps be advantageous to direct a certain portion of the inquiry. The metallic salts and calces are the combinations from which this principle is most commonly obtained; but the combinations of these with fat oils have hitherto afforded little promise of the improvement here sought. The subject is, however, so little known, that experiments of the loosest and most conjectural kind are by no means to be despised."

Thus

Candle.

Canongoes, Thus far Mr Nicholson : but it is probable that many of the advantages which he proposes by these mixtures might be obtained merely by purifying the tallow, and keeping it in that state for a long time exposed to the air before it be formed into candles. It is certain that tallow is rendered more difficult of fusion by age ; and this is the sole reason that old candles are less apt to run, and therefore more valuable than such as have been lately made.

CANONGOES, in Bengal, are the registers of land and hereditary expounders of the usages of the country. They have their officers and deputies everywhere ; they are not liable to removal ; and all papers attested by them are received as authentic and decisive in all disputes relative to lands and their boundaries. See *Sir Charles Rouse Boughton's Dissertation on the Landed Property of Bengal*.

CAOUTCHOUC, ELASTIC GUM, or *Indian Rubber*, is a substance of which a pretty full account has been given in the *Encyclopædi*. It has there been likewise observed how useful it might be, if we could form it into catheters and other flexible instruments, by dissolving it in a menstruum less expensive, or at least more easily attained, than ether. Since that article was published, we have seen an account of such a menstruum in the *Annales de Chimie*, by M. Grossart (Chirly) ; and of the expence of that menstruum, or the difficulty of procuring it, no complaint will be made, when it is known to be nothing more than very hot water.

The author was led to this discovery by some experiments made with ether on caoutchouc ; of which he gives the following account :

" It appeared, even in my first experiments, that I was attempting too much, and giving myself useless trouble, in searching for a manner of completely dissolving the elastic gum, so that it might be again made up in new forms. I then thought that it would be easier to find out a method, as it were, of folding it, and of not acting upon it more than might be necessary to cause its softened parts to reunite. Experience has shewn me, that a strong pressure made upon two pieces of caoutchouc (when brought to that state of softness) and continued until they are entirely dry, caused them to contract so strong an adhesion, that the piece, being pulled out till it broke, often broke, not at the united part, but by the side of it.

" By means of ether I immediately succeeded in making these tubes. The method which appears to me to succeed the best is, to cut a bottle circularly in a spiral slip of a few lines in breadth. It is very easy to cut a bottle in such a manner as to form a single long slip, and thus unnecessary joinings are avoided.

" The whole slip is to be plunged into ether until it is sufficiently softened, which comes to pass sooner or later according to the quality of the vitriolic ether that is employed. Half an hour frequently suffices ; but I have already observed, that there is a great diversity in the manner in which different sorts of vitriolic ether act, and of which the cause is not yet, so far as I know, determined.

" The slip being taken out, one of the extremities is to be taken hold of and rolled, first upon itself at the bottom of the tube, pressing it ; then the rolling is to be continued, mounting spirally along the mould, and taking care to lay over and compress with the hand

every edge, one against the other, so that there may not be any vacant space, and that all the edges may join exactly. The whole then is to be bound hard with a tape of an inch in width, taking care to turn it the same way with the slip of elastic gum. The tape is to be tied up with packthread, so that, by every turn of the packthread joining another, an equal pressure is given to every part : it is then left to dry, and the tube is made.

" The bandage is to be taken off with great care, that none of the outward surfaces, which may have been lodged within the hollows of the tape (of which the caoutchouc takes the exact impression), may be pulled away. I advise the application of a tape before packthread, because, especially in the thinner tubes, we should run the risk of cutting the caoutchouc if the packthread were applied immediately upon it.

" It is easy to take off the tube of elastic gum which has been formed upon a solid mould of one piece : if the mould be made rather conic, it may be made to slide off by the smaller end ; at the worst, it is easily accomplished by plunging it into hot water ; for it is softened by the heat, and is distended : without this precaution it would be sometimes difficult to draw it off when dry, because, having been applied upon the mould whilst it had its volume augmented by the interposition of the ether, the parts of the caoutchouc are drawn nearer each other by the evaporation of the interposed bodies.

" The great affinity between these two bodies is seen by the length of time that the odour of the ether remains, notwithstanding the great volatility of the latter, and that the apparent dryness of the tube seems to shew that there is none remaining ; nevertheless, after a certain time, the odour disappears entirely. One of those tubes, which was made with ether after the method here described, does not retain the least trace of the solvent. It is needless to say that it is easy to make tubes as thin or as thick as may be judged proper.

" Although the process that I am now describing is but very little expensive, yet I have tried to employ other solvents in lieu of ether, because it is not to be had in every place, and requires particular care in its preservation. I have employed, with some success, the essential oils of lavender and of turpentine : both of them speedily dilate the caoutchouc, and are of no great price. The disagreeable smell of the oil of turpentine becomes, perhaps, in process of time, less disagreeable than that of lavender. This last is dearer : but the difference is not so great as it appears at first ; for we may make some advantage of the oil of lavender that is employed by the following operation : Upon plunging into alcohol the elastic tube prepared with the oil of lavender, the alcohol charges itself with the oil, and forms a very good lavender water ; the same as would be made by an immediate mixture of oil of lavender with spirit of wine. Immersion in this liquor also serves to hasten the drying of the caoutchouc instruments thus made by means of essential oils. I have made tubes with the oils of turpentine and of lavender ; both are much slower in evaporating than ether. The oil of turpentine particularly appeared to me always to have a kind of stickiness, and I know not as yet that we have any means whereby to get speedily rid of its smell.

" Nevertheless there is a solvent which has not that

Caout-
chouc.

Cap.

inconvenience; it is cheaper, and may easily be procured by every one: this solvent is *water*. I conceive it will appear strange to mention water as a solvent of elastic gum, that liquid having been always supposed to have no action upon it. I myself resisted the idea; but reflecting that ether, by being saturated with water, is the better enabled to act on caoutchouc, and that this gum when plunged into boiling water becomes more transparent at the edges, I presumed that this effect was not due simply to the dilatation of its volume by the heat. I thought that, at that temperature, some action might take place, and that a long-continued ebullition might produce more sensible effects. I was not disappointed in my expectations, and one of those tubes was prepared without any other solvent than water and heat. I proceeded in the same manner as with ether: the elastic gum dilates but very little in boiling water; it becomes whitish, but recovers its colour again by drying it in the air and light. It is sufficiently prepared for use when it has been a quarter of an hour in boiling water: by this time its edges are sometimes transparent. It is to be turned spirally round the mould, in the manner we described before, and replunged frequently into the boiling water during the time that is employed in forming the tube, to the end that the edges may be disposed to unite together. When the whole is bound with packthread, it is to be kept some hours in boiling water; after which it is to be dried, still keeping on the binding.

"If we wish to be more certain that the connection is perfect, the spiral may be doubled; but we must always avoid placing the exterior surfaces of the slips one upon the other, as those surfaces are the parts which most resist the action of solvents. This precaution is less necessary when ether is employed, on account of its great action upon the caoutchouc.

"It might be feared that the action of water upon caoutchouc would deprive us of the advantages which might otherwise be expected; but these fears will be removed, if we consider that the affinities differ according to the temperatures; that it is only at a very high temperature that water exercises any sensible action upon caoutchouc. I can affirm, that at 120° of Reaumur's thermometer (302° of Fahrenheit) this affinity is not such as that the water can give a liquid form to caoutchouc; and it does not appear that we have any thing to fear in practice from a combination between these two bodies, which, though it really is a true solution, does not take place in any sensible degree but at a high temperature. It is therefore at present easy to make of caoutchouc whatever instruments it may be advantageous to have of a flexible, supple, and elastic substance, which is impermeable to water at the temperature of our atmosphere, and resists the action of acids as well as that of most other solvents. As to the durability of these instruments, few substances promise more than this, because it may be soldered afresh in a damaged part. Any woven substance may be covered with it; it is only required that the substance should be of a nature not to be acted upon during the preparation, either by ether or by boiling water; for these two agents are those which appear to me to merit the preference. Artists will frequently find an advantage in employing ether, as it requires less time; so that a person may make, in a single day, any tube he may have occasion for. The

expenditure of ether is very little, since it is needful only to dispose the caoutchouc to adhere; and being brought into that state, the caoutchouc may be kept in a vessel perfectly well closed. It would also diminish the expense of the ether if, instead of washing it with a large quantity of water, there should be added to it only as much water as it can take up."

CAP and BUTTON, are two small islands, or rather rocks, lying in longitude 105° 48' 35" east; and in latitude, the former 5° 58' 30", the latter 5° 49' south. They were visited by some of the persons attending Lord Macartney on his embassy to China; and are thus described by Sir George Staunton.

"At a little distance they might be mistaken for the remains of old castles, mouldering into heaps of ruins, with tall trees already growing upon the tops; but at a nearer view, they betrayed evident marks of a volcanic origin. Explosions from subterraneous fires, produce, for the most part, hills of a regular shape, and terminating in truncated cones; but when from a subaqueous volcano eruptions are thrown up above the surface of the sea, the materials, falling back into the water, are more irregularly dispersed, and generally leave the sides of the new creation naked and misshapen, as in the instance of AMSTERDAM, and of those smaller spots called, from some resemblance in shape, the Cap and Button.

"In the Cap were found two caverns, running horizontally into the side of the rock; and in these were a number of those birds nests so much prized by the Chinese epicures. They seemed to be composed of fine filaments cemented together by a transparent viscous matter, not unlike what is left by the foam of the sea upon stones alternately covered by the tide, or those gelatinous animal substances found floating on every coast. The nests adhere to each other, and to the sides of the cavern, mostly in rows, without any break or interruption. The birds that build these nests are small grey swallows, with bellies of a dirty white. They were flying about in considerable numbers; but they were so small, and their flight so quick, that they escaped the shot fired at them. The same nests are said also to be found in deep caverns, at the foot of the highest mountains in the middle of Java, and at a distance from the sea, from which the birds, it is thought, derive no materials, either for their food or the construction of their nests; as it does not appear probable they should fly, in search of either, over the intermediate mountains, which are very high, or against the boisterous winds prevailing thereabouts. They feed on insects, which they find hovering over stagnated pools between the mountains, and for catching which their wide opening beaks are particularly adapted. They prepare their nests from the best remnants of their food. Their greatest enemy is the kite, who often intercepts them in their passage to and from the caverns, which are generally surrounded with rocks of grey limestone or white marble. The nests are placed in horizontal rows at different depths, from 50 to 500 feet. The colour and value of the nests depend on the quantity and quality of the insects caught, and perhaps also on the situation where they are built. Their value is chiefly determined by the uniform fineness and delicacy of their texture; those that are white and transparent being most esteemed, and fetching often in China their weight in silver.

These

Cap.

These nests are a considerable object of traffic among the Javanese, and many are employed in it from their infancy. The birds having spent near two months in preparing their nests, lay each two eggs, which are hatched in about fifteen days. When the young birds become fledged, it is thought time to seize upon their nests, which is done regularly thrice a-year, and is effected by means of ladders of bamboo and reeds, by which the people descend into the cavern; but when it is very deep, rope ladders are preferred. This operation is attended with much danger; and several break their necks in the attempt. The inhabitants of the mountains generally employed in it begin always by sacrificing a buffalo; which custom is constantly observed by the Javanese on the eve of every extraordinary enterprise. They also pronounce some prayers, anoint themselves with sweet-scented oil, and smoke the entrance of the cavern with gum-benjamin. Near some of those caverns a tutelary goddess is worshipped, whose priest burns incense, and lays his protecting hands on every person preparing to descend into the cavern. A flambeau is carefully prepared at the same time, with a gum which exudes from a tree growing in the vicinity, and is not easily extinguished by fixed air or subterraneous vapours. The swallow which builds those nests is described as not having its tail feathers marked with

white spots, which is a character attributed to it by Linnæus; and it is possible that there are two species or varieties of the swallow, whose nests are alike valuable." See *BIRDS-Nests*, *Encycl.*

CAPE OF GOOD HOPE. See *GOOD HOPE*, both in *Encycl.* and this *Supplement*.

CAPITAL OF A BASTION, is an imaginary line dividing any work into two equal and similar parts; or a line drawn from the angle of the polygon to the point of the bastion, or from the point of the bastion to the middle of the gorge.

CAPRA, or the SHE-GOAT, a name given to the star Capella, on the left shoulder of Auriga, and sometimes to the constellation Capricorn. Some again represent Capra as a constellation in the northern hemisphere, consisting of three stars, comprised between the 45th and 55th degree of latitude.—The poets fable her to be Amalthea's goat, which suckled Jupiter in his infancy.

CAPUT DRACONIS, or *Dragon's Head*, a name given by some to a fixed star of the first magnitude, in the head of the constellation Draco.

CARBON. See *CHEMISTRY* in this *Supplement*, Part I. Chap. II. Sect. iii.

CARP. See *CYPRINUS*, both in the *Encycl.* and in this *Supplement*.

Cape

||

Carp.

CARPENTRY,

¹
Definition.

THE art of framing timber for the purposes of architecture, machinery, and, in general, for all considerable structures.

It is not intended in this article to give a full account of carpentry as a *mechanical* art, or to describe the various ways of executing its different works, suited to the variety of materials employed, the processes which must be followed for fashioning and framing them for our purposes, and the tools which must be used, and the manner in which they must be handled: This would be an occupation for volumes; and though of great importance, must be entirely omitted here. Our only aim at present will be to deduce, from the principles and laws of mechanics, and the knowledge which experience and judicious inferences from it have given us concerning the strength of timber, in relation to the strain laid on it, such maxims of construction as will unite economy with strength and efficacy.

This object is to be attained by a knowledge, 1st, of the strength of our materials, and of the absolute strain that is to be laid on them; 2dly, of the modifications of this strain, by the place and direction in which it is exerted, and the changes that can be made by a proper disposition of the parts of our structure; and, 3dly, having disposed every piece in such a manner as to derive the utmost advantage from its relative strength, we must know how to form the joints and other connections in such a manner as to secure the advantages derived from this disposition.

²
An important branch of mechanical science

This is, evidently, a branch of mechanical science, which makes carpentry a *liberal* art, constitutes part of the learning of the *ENGINEER*, and distinguishes him from the workman. Its importance in all times and states of civil society is manifest and great. In the pre-

sent condition of these kingdoms, raised, by the active ingenuity and energy of our countrymen, to a pitch of prosperity and influence unequalled in the history of the world, a condition which consists chiefly in the superiority of our manufactures, attained by prodigious multiplication of engines of every description, and for every species of labour, the *SCIENCE* (so to term it) of carpentry is of immense consequence. We regret therefore exceedingly, that none of our celebrated artists have done honour to themselves and their country, by digesting into a body of consecutive doctrines the results of their great experience, so as to form a system from which their pupils might derive the first principles of their education. The many volumes called *COMPLETE INSTRUCTORS*, *MANUALS*, *JEWELS*, &c. take a much humbler flight, and content themselves with instructing the mere workman, or sometimes give the master-builder a few approved forms of roofs and other framings, with the rules for drawing them on paper; and from thence forming the working draughts which must guide the saw and the chisel of the workman. Hardly any of them offer any thing that can be called a principle, applicable to many particular cases, with the rules for this adaptation. We are indebted for the greatest part of our knowledge of this subject to the labours of literary men, chiefly foreigners, who have published in the memoirs of the learned academies dissertations on different parts of what may be termed the *science of carpentry*. It is singular that the members of the Royal Society of London, and even of that established and supported by the patriotism of these days for the encouragement of the arts, have contributed so little to the public instruction in this respect. We observe of late some beginnings of this kind, such as the last part of

3

Principally indebted to foreigners for a knowledge of this subject.

Nicholson's CARPENTERS AND JOINERS ASSISTANT, published by J. Taylor, Holborn, 1797. And it is with pleasure that we can say, that we were told by the editor, that this work was prompted in a great measure by what has been delivered in the *Encyclopædia Britannica* in the articles ROOF and STRENGTH of Materials. It abounds more in important and new observations than any book of the kind that we are acquainted with. We again call on such as have given a scientific attention to this subject, and pray that they would render a meritorious service to their country by imparting the result of their researches. The very limited nature of this work does not allow us to treat the subject in detail; and we must confine our observations to the fundamental and leading propositions.

4
Theory,
founded on
what.

The theory (so to term it) of carpentry is founded on two distinct portions of mechanical science, namely, a knowledge of the strains to which framings of timber are exposed, and a knowledge of their relative strength.

We shall therefore attempt to bring into one point of view the propositions of mechanical science that are more immediately applicable to the art of carpentry, and are to be found in various articles of our work, particularly ROOF and STRENGTH of Materials. From these propositions we hope to deduce such principles as shall enable an attentive reader to comprehend distinctly what is to be aimed at in framing timber, and how to attain this object with certainty: and we shall illustrate and confirm our principles by examples of pieces of carpentry which are acknowledged to be excellent in their kind.

5
Composition and resolution of forces

The most important proposition of general mechanics to the carpenter is that which exhibits the composition and resolution of forces; and we beg our practical readers to endeavour to form very distinct conceptions of it, and to make it very familiar to their mind. When accommodated to their chief purposes, it may be thus expressed:

Plate VIII.

1. If a body, or any part of a body, be at once pressed in the two directions AB, AC (fig. 1.), and if the intensity or force of those pressures be in the proportion of these two lines, the body is affected in the same manner as if it were pressed by a single force acting in the direction AD, which is the diagonal of the parallelogram ABDC formed by the two lines, and whose intensity has the same proportion to the intensity of each of the other two that AD has to AB or AC.

Such of our readers as have studied the laws of motion, know that this is fully demonstrated. We refer them to the article MECHANICS, n^o 5, &c. where it is treated at some length. Such as wish for a very accurate view of this proposition, will do well to read the demonstration given by D. Bernoulli, in the first volume of the *Comment. Petropol.* and the improvement of this demonstration by D'Alembert in his *Opuscles*, and in the *Comment. Taurinens.* The practitioner in carpentry will get more useful confidence in the doctrine, if he will shut his book, and verify the theoretical demonstrations by actual experiments. They are remarkably easy and convincing. Therefore it is our request that the artist, who is not so habitually acquainted with the subject, do not proceed further till he has made it quite familiar to his thoughts. Nothing is so conducive to this as the actual experiment; and since this on-

6
Illustrated
by experi-
ment.

ly requires the trifling expence of two small pulleys and a few yards of whipcord, we hope that none of our practical readers will omit it: They will thank us for this injunction.

2. Let the threads A d, AF b, and AE c (fig. 2.), have the weights d, b, and c, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus the knot A will be drawn in the directions AB, AC, and AK. If the sum of the weights b and c be greater than the single weight d, the assemblage will of itself settle in a certain determined form; if you pull the knot A out of its place, it will always return to it again, and will rest in no other position. For example, if the three weights are equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle opposite to the thread stretched by five pounds will always be square, &c. When the knot A is thus in equilibrio, we must infer, that the action of the weight d, in the direction A d, is in direct opposition to the combined action of b, in the direction AB, and of c, in the direction AC. Therefore, if we produce dA to any point D, and take AD to represent the magnitude of the force, or pressure exerted by the weight d, the pressures exerted on A by the weights b and c, in the directions AB, AC, are in fact equivalent to a pressure acting in the direction AD, whose intensity we have represented by AD. If we now measure off by a scale on AF and AE the lines AB and AC, having the same proportions to AD that the weights b and c have to the weight d, and if we draw DB and DC, we shall find DC to be equal and parallel to AB, and DB equal and parallel to AC; so that AD is the diagonal of a parallelogram ABDC. We shall find this always to be the case, whatever are the weights made use of; only we must take care that the weight which we cause to act without the intervention of a pulley be less than the sum of the other two: if any one of the weights exceeds the sum of the other two, it will prevail, and drag them along with it.

Now, since we know that the weight d would just balance an equal weight g, pulling directly upwards by the intervention of the pulley G; and since we see that it just balances the weights b and c, acting in the directions AB, AC, we must infer, that the knot A is affected in the same manner by those two weights, or by the single weight g; and therefore that two pressures, acting in the directions, and with the intensities, AB, AC, are equivalent to a single pressure having the direction and proportion of AD. In like manner, the pressures AB, AK, are equivalent to AH, which is equal and opposite to AC. Also AK and AC are equivalent to AI, which is equal and opposite to AB.

We shall consider this combination of pressures a little more particularly.

Suppose an upright beam BA (fig. 3.) pushed in the direction of its length by a load B, and abutting on the ends of two beams AC, AD, which are firmly resisted at their extreme points C and D, which rest on two blocks, but are nowise joined to them: these two beams can resist no way but in the directions CA, DA; and therefore the pressures which they sustain from the beam BA are in the directions AC, AD. We wish to know how much each sustains? Produce BA to E, taking

7
Considered
more parti-
cularly.

taking AE from a scale of equal parts, to represent the number of tons or pounds by which BA is pressed. Draw EF and EG parallel to AD and AC; then AF, measured on the same scale, will give us the number of pounds by which AC is strained or crushed, and AG will give the strain on AD.

It deserves particular remark here, that the length of AC or AD has no influence on the strain, arising from the thrust of BA, while the directions remain the same. The effects, however, of this strain are modified by the length of the piece on which it is exerted. This strain compresses the beam, and will therefore compress a beam of double length twice as much. This may change the form of the assemblage. If AC, for example, be very much shorter than AD, it will be much less compressed: The line CA will turn about the centre C, while DA will hardly change its position; and the angle CAD will grow more open, the point A sinking down. The artist will find it of great consequence to pay a very minute attention to this circumstance, and to be able to see clearly the change of shape which necessarily results from these mutual strains. He will see in this the cause of failure in many very great works.—By thus changing shape, strains are often produced in places where there were none before, and frequently of the very worst kind, tending to break the beams across.

The dotted lines of this figure shew another position of the beam AD'. This makes a prodigious change, not only in the strain on AD', but also in that on AC. Both of them are much increased; AG is almost doubled, and AF is four times greater than before. This addition was made to the figure, to shew what enormous strains may be produced by a very moderate force AE, when it is exerted on a very obtuse angle.

The 4th and 5th figures will assist the most uninitiated reader in conceiving how the very same strains AF, AG, are laid on these beams, by a weight simply hanging from a billet resting on A, pressing hard on AD, and also leaning a little on AC; or by an upright piece AE, joggled on the two beams AC, AD, and performing the office of an ordinary king-post. The reader will thus learn to call off his attention from the means by which the strains are produced, and learn to consider them abstractedly, merely as strains, in whatever situation he finds them, and from whatever cause they arise.

We presume that every reader will perceive, that the proportions of these strains will be precisely the same if every thing be inverted, and each beam be drawn or pulled in the opposite direction. In the same way that we have substituted a rope and weight in fig. 4. or a king-post in fig. 5. for the loaded beam BA of fig. 3. we might have substituted the framing of fig. 6. which is a very usual practice. In this framing, the batten DA is stretched by a force AG, and the piece AC is compressed by a force AF. It is evident that we may employ a rope, or an iron rod hooked on at D, in place of the batten DA, and the strains will be the same as before.

This seemingly simple matter is still full of instruction; and we hope that the well-informed reader will pardon us, though we dwell a little longer on it for the sake of the young artist.

By changing the form of this framing, as in fig. 7. we produce the same strains as in the disposition repre-

sented by the dotted lines in fig. 3. The strains on both the battens AD, AC, are now greatly increased.

The same consequences result from an improper change of the position of AC. If it is placed as in fig. 8. the strains on both are vastly increased. In short, the rule is general; that the more open we make the angle against which the push is exerted, the greater are the strains which are brought on the struts or ties which form the sides of the angle.

The reader may not readily conceive the piece AC of fig. 8. as sustaining a compression; for the weight B appears to hang from AC as much as from AD. But his doubts will be removed by considering whether he could employ a rope in place of AC. He cannot: But AD may be exchanged for a rope. AC is therefore a strut and not a tie.

In fig. 9. AD is again a strut, butting on the block D, and AC is a tie: and the batten AC may be replaced by a rope. While AD is compressed by the force AG, AC is stretched by the force AF.

If we give AC the position represented by the dotted lines, the compression of AD is now AG', and the force stretching AC' is now AF'; both much greater than they were before. This disposition is analogous to fig. 8. and to the dotted lines in fig. 3. Nor will the young artist have any doubts of AC' being on the stretch, if he consider whether AD can be replaced by a rope. It cannot, but AC' may; and it is therefore not compressed, but stretched.

In fig. 10. all the three pieces, AC, AD, and AB, are ties on the stretch. This is the complete inversion of fig. 3.; and the dotted position of AC induces the same changes in the forces AF', AG', as in fig. 3.

Thus have we gone over all the varieties which can happen in the bearings of three pieces on one point. All calculations about the strength of carpentry are reduced to this case: for when more ties or braces meet in a point (a thing that rarely happens), we reduce them to three, by substituting for any two the force which results from their combination, and then combining this with another; and so on.

The young artist must be particularly careful not to mistake the kind of strain that is exerted on any piece of the framing, and suppose a piece to be a brace which is really a tie. It is very easy to avoid all mistakes in this matter by the following rule, which has no exception.

Take notice of the direction in which the piece acts from which the strain proceeds. Draw a line in that direction from the point on which the strain is exerted; and let its length (measured on some scale of equal parts) express the magnitude of this action in pounds, hundreds, or tons. From its remote extremity draw lines parallel to the pieces on which the strain is exerted. The line parallel to one piece will necessarily cut the other, or its direction produced: If it cut the piece itself, that piece is compressed by the strain, and it is performing the office of a strut or brace: if it cut its direction produced, the piece is stretched, and it is a tie. In short, the strains on the pieces AC, AD, are to be estimated in the direction of the points F and G from the strained point A. Thus, in fig. 3. the upright piece BA, loaded with the weight B, presses the point A in the direction AE: so does the rope AB in the other figures, or the batten AB in fig. 5.

8
Rule for distinguishing the cases of compression and extension.

In

CARPENTRY.

In general, if the straining piece is within the angle formed by the pieces which are strained, the strains which they sustain are of the opposite kind to that which it exerts. If it be pushing, they are drawing; but if it be within the angle formed by their directions produced, the strains which they sustain are of the same kind. All the three are either drawing or pressing. If the straining piece lie within the angle formed by one piece and the produced direction of the other, its own strain, whether compression or extension, is of the same kind with that of the most remote of the other two, and opposite to that of the nearest. Thus, in fig. 9. where AB is drawing, the remote piece AC is also drawing, while AD is pushing or resisting compression.

In all that has been said on this subject, we have not spoken of any joints. In the calculations with which we are occupied at present, the resistance of joints has no share; and we must not suppose that they exert any force which tends to prevent the angles from changing. The joints are supposed perfectly flexible, or to be like compass joints; the pin of which only keeps the pieces together when one or more of the pieces draws or pulls. The carpenter must always suppose them all compass joints when he calculates the thrusts and draughts of the different pieces of his frames. The strains on joints, and their power to produce or balance them, are of a different kind, and require a very different examination.

9
General expression of the magnitude of the strain.

Seeing that the angles which the pieces make with each other are of such importance to the magnitude and the proportion of the excited strains, it is proper to find out some way of readily and compendiously conceiving and expressing this analogy.

In general, the strain on any piece is proportional to the straining force. This is evident.

Secondly, the strain on any piece AC is proportional to the sine of the angle, which the straining force makes with the other piece directly, and to the sine of the angle which the pieces make with each other inversely.

For it is plain, that the three pressures AE, AF, and AG, which are exerted at the point A, are in the proportion of the lines AE, AF, and FE (because FE is equal to AG). But because the sides of a triangle are proportional to the sines of the opposite angles, the strains are proportional to the sines of the angles AFE, AEF, and FAE. But the sine of AFE is the same with the sine of the angle CAD, which the two pieces AC and AD make with each other; and the sine of AEF is the same with the sine of EAD, which the straining piece BA makes with the piece AC. Therefore we have this analogy, Sin. CAD : Sin. EAD = AE : AF, and $AF = AE \times \frac{\text{Sin. EAD}}{\text{Sin. CAD}}$.—Now the

sines of angles are most conveniently conceived as decimal fractions of the radius, which is considered as unity. Thus, Sin. 30° is the same thing with 0,5, or $\frac{1}{2}$; and so of others. Therefore, to have the strain on AC, arising from any load AE acting in the direction AE, multiply AE by the sine of EAD, and divide the product by the sine of CAD.

This rule shews how great the strains must be when the angle CAD becomes very open, approaching to 180 degrees. But when the angle CAD becomes very small, its sine (which is our divisor) is also very small; and we should expect a very great quotient in this case also. But we must observe, that in this case the sine of

EAD is also very small; and this is our multiplier. In such a case, the quotient cannot exceed unity.

But it is unnecessary to consider the calculation by the tables of sines more particularly. The angles are seldom known any otherwise but by drawing the figure of the frame of carpentry. In this case, we can always obtain the measures of the strains from the same scale, with equal accuracy, by drawing the parallelogram AFCG.

Hitherto we have considered the strains excited at A only as they affect the pieces on which they are exerted. But the pieces, in order to sustain, or be subjected to, any strain, must be supported at their ends C and D; and we may consider them as mere intermediums, by which these strains are made to act on those points of support: Therefore AF and AG are also measures of the forces which press or pull at C and D. Thus we learn the supports which must be found for these points. These may be infinitely various. We shall attend only to such as somehow depend on the framing itself.

Such a structure as fig. 11. very frequently occurs, where a beam BA is strongly pressed to the end of another beam AD, which is prevented from yielding, both because it lies on another beam HD, and because its end D is hindered from sliding backwards. It is indifferent from what this pressure arises: we have represented it as owing to a weight hung on at B, while B is withheld from yielding by a rod or rope hooked to the wall. The beam AD may be supposed at full liberty to exert all its pressure on D, as if it were supported on rollers lodged in the beam HD; but the loaded beam BA presses both on the beam AD and on HD. We wish only to know what strain is borne by AD?

All bodies act on each other in the direction perpendicular to their touching surfaces; therefore the support given by HD is in a direction perpendicular to it. We may therefore supply its place at A by a beam AC, perpendicular to HD, and firmly supported at C. In this case, therefore, we may take AE, as before, to represent the pressure exerted by the loaded beam, and draw EG perpendicular to AD, and EF parallel to it, meeting the perpendicular AC in F. Then AG is the strain compressing AD, and AF is the pressure on the beam HD.

It may be thought, that since we assume as a principle that the mutual pressures of solid bodies are exerted perpendicular to their touching surfaces, this balance of pressures, in framings of timbers, depends on the directions of their butting joints: but it does not, as will readily appear by considering the present case. Let the joint or abutment of the two pieces BA, AD be mitred, in the usual manner, in the direction $f A f'$. Therefore, if $A e$ be drawn perpendicular to $A f$, it will be the direction of the actual pressure exerted by the loaded beam BA on the beam AD. But the reaction of AD, in the opposite direction $A t$, will not balance the pressure of BA; because it is not in the direction precisely opposite. BA will therefore slide along the joint, and press on the beam HD. AE represents the load on the mitre joint A. Draw $E e$ perpendicular to $A e$, and $E f$ parallel to it. The pressure AE will be balanced by the reactions $e A$ and $f A$: or, the pressure AE produces the pressures $A e$ and $A f$;

To Strains propagated to the points of support.

11
Action of a straining beam.

12
The form of the abutting joint of no great importance.

of which Af must be resisted by the beam HD , and Ae by the beam AD . The pressure Af not being perpendicular to HD , cannot be fully resisted by it; because (by our assumed principle) it reacts only in a direction perpendicular to its surface. Therefore draw fp, fi parallel to HD , and perpendicular to it. The pressure Af will be resisted by HD with the force pA ; but there is required another force iA , to prevent the beam BA from slipping outwards. This must be furnished by the reaction of the beam DA .—In like manner, the other force Ae cannot be fully resisted by the beam AD , or rather by the prop D , acting by the intervention of the beam; for the action of that prop is exerted through the beam in the direction DA . The beam AD , therefore, is pressed to the beam HD by the force Ae , as well as by Af . To find what this pressure on HD is, draw eg perpendicular to HD , and eo parallel to it, cutting EG in r . The forces gA and oA will resist, and balance Ae .

Thus we see, that the two forces Ae and Af , which are equivalent to AE , are equivalent also to Ap, Ai, Ao , and Ag . But because Af and E are equal and parallel, and Er and fi are also parallel, as also er and fp , it is evident, that if is equal to re , or to oF , and iA is equal to re , or to Gg . Therefore the four forces Ag, Ao, Ap, Ai , are equal to AG and AF . Therefore AG is the compression of the beam AD , or the force pressing it on D , and AF is the force pressing it on the beam HD . The proportion of these pressures, therefore, is not affected by the form of the joint.

This remark is important; for many carpenters think the form and direction of the butting-joint of great importance; and even the theorist, by not prosecuting the general principle through all its consequences, may be led into an error. The form of the joint is of no importance, in as far as it affects the strains in the direction of the beams; but it is often of great consequence, in respect to its own firmness, and the effect it may have in bruising the piece on which it acts, or being crippled by it.

The same compression of AB , and the same thrust on the point D by the intervention of AD , will obtain, in whatever way the original pressure on the end A is produced. Thus supposing that a cord is made fast at A , and pulled in the direction AE , and with the same force, the beam AD will be equally compressed, and the prop D must react with the same force.

But it often happens that the obliquity of the pressure on AD , instead of compressing it, stretches it; and we desire to know what tension it sustains? Of this we have a familiar example in a common roof. Let the two rafters AC, AD (fig. 12.), press on the tie-beam DC . We may suppose the whole weight to press vertically on the ridge A , as if a weight B were hung on there. We may represent this weight by the portion Ab of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing bf and bg parallel to AD and AC, Ag and Af will represent the pressures on AC and AD . Produce AC till CH be equal to Af . The point C is forced out in this direction, and with a force represented by this line. As this force is not perpendicularly across the beam, it evidently stretches it; and this extending force must be withstood by an equal force pulling it in the opposite direction. This must arise from a similar oblique thrust

of the opposite rafter on the other end D . We concern ourselves only with this extension at present; but we see that the cohesion of the beam does nothing but supply the balance to the extending forces. It must still be supported externally, that it may resist, and, by resisting obliquely, be stretched. The points C and D are supported on the walls, which they press in the directions CK and DO , parallel to Ab . If we draw HK parallel to DC , and HI parallel to CK (that is, to Ab), meeting DC produced in I , it follows from the composition of forces, that the point C would be supported by the two forces KC and IC . In like manner, making $DN = Ag$, and completing the parallelogram $DMNO$, the point D would be supported by the forces OD and MD . If we draw go and fk parallel to DC , it is plain that they are equal to NO and CK , while Ao and Ak are equal to DO and CK , and Ab is equal to the sum of DO and CK (because it is equal to $Ao + Ak$). The weight of the roof is equal to its vertical pressure on the walls.

Thus we see, that while a pressure on A , in the direction Ab , produces the strains Af and Ag , on the pieces AC and AD , it also excites a strain CI or DM in the piece DC . And this completes the mechanism of a frame; for all derive their efficacy from the triangles of which they are composed, as will appear more clearly as we proceed.

But there is more to be learned from this. The consideration of the strains on the two pieces AD and AC , by the action of a force at A , only shewed them as the means of propagating the same strains in their own direction to the points of support. But, by adding the strains exerted in DC , we see that the frame becomes an intermedium, by which exertions may be made on other bodies, in certain directions and proportions; so that this frame may become part of a more complicated one, and, as it were, an element of its constitution. It is worth while to ascertain the proportion of the pressures CK and DO , which are thus exerted on the walls. The similarity of triangles gives the following analogies:

$$DO : DM = Ab : bD$$

$$CI, \text{ or } DM : CK = Cb : bD$$

$$\text{Therefore } DO : CK = Cb : bD.$$

Or, the pressures on the points C and D , in the direction of the straining force Ab , are reciprocally proportional to the portions of DC intercepted by Ab .

Also, since Ab is $= DO + CK$, we have

$$Ab : CK = Cb + bD \text{ (or } CD) : bD, \text{ and}$$

$$Ab : DO = CD : bC.$$

In general, any two of the three parallel forces Ab, DO, CK , are to each other in the reciprocal proportion of the parts of CD , intercepted between their directions and the direction of the third.

And this explains a still more important office of the frame ADC . If one of the points, such as D , be supported, an external power acting at A , in the direction Ab , and with an intensity which may be measured by Ab , may be set in equilibrio, with another acting at C , in the direction CL , opposite to CK or Ab , and with an intensity represented by CK : for since the pressure CH is partly withstood by the force IC , or the firmness of the beam DC supported at D , the force KC will complete the balance. When we do not attend to the support at D , we conceive the force Ab to be balanced

by

13
Origin of the strain on a tie-beam.

14
External action of a frame.

by KC, or KC to be balanced by *A b*. And, in like manner, we may neglect the support or force acting at A, and consider the force DO as balanced by CK.

15
It becomes
a lever.

Thus our frame becomes a lever, and we are able to trace the interior mechanical procedure which gives it its efficacy: it is by the intervention of the forces of cohesion, which connect the points to which the external forces are applied with the supported point or fulcrum, and with each other.

These strains or pressures *A b*, DO, and CK, not being in the directions of the beams, may be called *transverse*. We see that by their means a frame of carpentry may be considered as a solid body: but the example which brought this to our view is too limited for explaining the efficacy which may be given to such constructions. We shall therefore give a general proposition, which will more distinctly explain the procedure of nature, and enable us to trace the strains as they are propagated through all the parts of the most complicated framing, finally producing the exertion of its most distant points.

16
General
proposition.

We presume that the reader is now pretty well habituated to the conception of the strains as they are propagated along the lines joining the points of a frame, and we shall therefore employ a very simple figure.

Let the strong lines ACBD (fig. 13.) represent a frame of carpentry. Suppose that it is pulled at the point A by a force acting in the direction AE, but that it rests on a fixed point C, and that the other extreme point B is held back by a power which resists in the direction BF: It is required to determine the proportion of the strains excited in its different parts, the proportion of the external pressures at A and B, and the pressure which is produced on the obstacle or fulcrum C?

It is evident that each of the external forces at A and B tend one way, or to one side of the frame, and that each would cause it to turn round C if the other did not prevent it; and that if, notwithstanding their action, it is turned neither way, the forces in actual exertion are in equilibrio by the intervention of the frame. It is no less evident that these forces concur in pressing the frame on the prop C. Therefore, if the piece CD were away, and if the joints C and D be perfectly flexible, the pieces CA, CB would be turned round the prop C, and the pieces AD, DB would also turn with them, and the whole frame change its form. This shews, by the way, and we desire it to be carefully kept in mind, that the firmness or stiffness of framing depends entirely on the triangles bounded by beams which are contained in it. An open quadrilateral may always change its shape, the sides revolving round the angles. A quadrilateral may have an infinity of forms, without any change of its sides, by merely pushing two opposite angles towards each other, or drawing them asunder. But when the three sides of a triangle are determined, its shape is also invariably determined; and if two angles be held fast, the third cannot be moved. It is thus that, by inserting the bar CD, the figure becomes unchangeable; and any attempt to change it by applying a force to an angle A, immediately excites forces of attraction or repulsion between the particles of the stuff which form its sides. Thus it happens, in the present instance, that a change of shape is prevented by the bar CD. The power at A presses its end against

the prop; and in doing this it puts the bar AD on the stretch, and also the bar DB. Their places might therefore be supplied by cords or metal wires. Hence it is evident that DC is compressed, as is also AC: and, for the same reason, CB is also in a state of compression; for either A or B may be considered as the point that is impelled or withheld. Therefore DA and DB are stretched, and are resisting with attractive forces. DC and CB are compressed, and are resisting with repulsive forces. DB is also acting with repulsive forces, being compressed in like manner: and thus the support of the prop, combined with the firmness of DC, puts the frame ADBC into the condition of the two frames in fig. 8. and fig. 9. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction AD, and a repulsive force acting in the direction AK. And since all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction DA. The condition of the point B is similar to that of A, and D is also drawn in the direction DB. Thus the point D, being urged by the forces in the directions DA and DB, presses the beam DC on the prop, and the prop resists in the opposite direction. Therefore the line DC is the diagonal of the parallelogram, whose sides have the proportion of the forces which connect D with A and B. This is the principle on which the rest of our investigation proceeds. We may take DC as the representation and measure of their joint effect. Therefore draw CH, CG, parallel to DA, DB. Draw HL, GO, parallel to CA, CB, cutting AE, BF in L and O, and cutting DA, DB in I and M. Complete the parallelograms ILKA, MONB. Then DG and AI are the equal and opposite forces which connect A and D; for $GD = CH = AI$. In like manner DH and BM are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces, connecting A with D and with C. AI is one of them: Therefore AK is the other; and AL is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and opposite to AL. In like manner, the external force at B is equal and opposite to BO; and AL is to BO as the external force at A to the external force at B. The prop C resists with forces equal to those which are propagated to it from the points D, A, and C. Therefore it resists with forces CH, CG, equal and opposite to DG, DH; and it resists the compressions KA, NB, with equal and opposite forces C*k*, C*n*. Draw *kl*, *no* parallel to AD, BD, and draw C*l*Q, C*o*P: It is plain that *k*CH*l* is a parallelogram equal to KAIL, and that C*l* is equal to AL. In like manner C*o* is equal to BO. Now the forces C*k*, CH, exerted by the prop, compose the force C*l*; and C*n*, CG compose the force C*o*. These two forces C*l*, C*o* are equal and parallel to AL and BO; and therefore they are equal and opposite to the external forces acting at A and B. But they are (primitively) equal and opposite to the pressures (or at least the compounds of the pressures) exerted on the prop, by the forces propagated to C from A, D, and B. Therefore the pressures exerted on the prop are the same as if the external forces were applied there in the same directions as they are applied to A and B. Now if we make CV, CZ equal to C*l* and C*o*,

and

and complete the parallelogram CVYZ; it is plain that the force YC is in equilibrio with /C and oC. Therefore the pressures at A, C, and B, are such as would balance if applied to one point.

Lastly, in order to determine their proportions, draw CS and CR perpendicular to DA and DB. Also draw A d, B f perpendicular to CQ and CP; and draw C g, C i perpendicular to AE, BF.

The triangles CPR and B P f are similar, having a common angle P, and a right angle at R and f.

In like manner the triangles CQS and A Q d are similar. Also the triangles CHR, CGS are similar, by reason of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

$$\begin{aligned} Co : CP &= On : PB, = CG : PB \\ CP : CR &= PB : f B \\ CR : CS &= CH : CG \\ CS : CQ &= Ad : A Q \\ CQ : C l &= A Q : K l, = A Q : C H. \end{aligned}$$

Therefore, by equality,

$$\begin{aligned} Co : C l &= Ad : f B \\ \text{or } BO : AL &= C g : C i. \end{aligned}$$

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction (A).

17
Extensive
consequences.

This proposition (sufficiently general for our purpose) is fertile in consequences, and furnishes many useful instructions to the artist. The strains LA, OB, CY, that are excited, occur, in many, we may say in all, framings of carpentry, whether for edifices or engines, and are the sources of their efficacy. It is also evident, that the doctrine of the transverse strength of timber is contained in this proposition; for every piece of timber may be considered as an assemblage of parts, connected by forces which act in the direction of the lines which join the strained points on the matter which lies between those points, and also act on the rest of the matter, exciting those lateral forces which produce the inflexibility of the whole. See *STRENGTH of Materials*, Encycl.

Thus it appears that this proposition contains the principles which direct the artist to frame the most powerful levers; to secure uprights by shores or braces, or by ties and ropes; to secure scaffoldings for the erection of spires, and many other most delicate pro-

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blems of his art. He also learns, from this proposition, how to ascertain the strains that are produced, without his intention, by pieces which he intended for other offices, and which, by their transverse action, put his work in hazard. In short, this proposition is the key to the science of his art.

We would now counsel the artist, after he has made the tracing of the strains and thrusts through the various parts of a frame familiar to his mind, and even amused himself with some complicated fancy framings, to read over with care the articles *STRENGTH of Materials* and *ROOF* in the *Encyclopædia Britannica*. He will now conceive its doctrines much more clearly than when he was considering them as abstract theories. The mutual action of the woody fibres will now be easily comprehended, and his confidence in the results will be greatly increased.

There is a proposition (no 19. in the article *ROOF*) which has been called in question by several very intelligent persons; and they say that Belidor has demonstrated, in his *SCIENCE DES INGENIEURS*, that a beam firmly fixed at both ends is not twice as strong as when simply lying on the props, and that its strength is increased only in the proportion of 2 to 3; and they support this determination by a list of experiments recited by Belidor, which agree *precisely* with it. Belidor also says that Pitot had the same result in his experiments. These are respectable authorities: but Belidor's reasoning is any thing but demonstration; and his experiments are described in such an imperfect manner, that we cannot build much on them. It is not said in what manner the battens were secured at the ends, any farther than that it was by *chevalets*. If by this word is meant a tressle, we cannot conceive how they were employed; but we see it sometimes used for a wedge or key. If the battens were wedged in the holes, their resistance to fracture may be made what we please: they may be loose, and therefore resist little more than when simply laid on the props. They may be (and probably were) wedged very fast, and bruised or crippled.

18
Decision of
a disputed
and very
important
question.

Our proposition mentioned distinctly the security given to the ends of the beams. They were mortised into remote posts. Our *precise* meaning was, that they were simply kept from rising by these mortises, but at full liberty to bend up between E and I, and between

Y G

(A) The learned reader will perceive, that this analogy is precisely the same with that of forces which are in equilibrio by the intervention of a lever. In fact, this whole frame of carpentry is nothing else than a *built or framed lever* in equilibrio. It is acting in the same manner as a solid, which occupies the whole figure compressed in the frame, or as a body of any size and shape whatever that will admit the three points of application A, C, and B. It is always in equilibrio in the case first stated; because the pressure produced at B by a force applied to A is always such as balances it. The reader may also perceive, in this proposition, the analysis or tracing of those internal mechanical forces which are indispensably requisite for the functions of a lever. The mechanicians have been extremely puzzled to find a legitimate demonstration of the equilibrium of a lever ever since the days of Archimedes. Mr Vince has the honour of first demonstrating, most ingeniously, the principle assumed by Archimedes, but without sufficient ground, for his demonstration: but Mr Vince's demonstration is only a putting the mind into that perplexed state which makes it acknowledge the proposition, but without a clear perception of its truth. The difficulty has proceeded from the abstract notion of a lever, conceiving it as a mathematical line—inflexible, without reflecting how it is inflexible—for the very source of this indispensable quality furnishes the mechanical connection between the remote pressures and the fulcrum; and this supplies the demonstration (without the least difficulty) of the desperate case of a straight lever urged by parallel forces. See *ROTATION*, no 11. *Encycl.*

G and K. Our assertion was not made from theory alone (although we think the reasoning incontrovertible), but was agreeable to numerous experiments made in those precise circumstances. Had we mortised the beams firmly into two very stout posts, which could not be drawn nearer to each other by bending, the beam would have borne a *much* greater weight, as we have verified by experiment. We hope that the following mode of conceiving this case will remove all doubts.

Let LM be a long beam (fig. 14.) divided into six equal parts, in the points D, B, A, C, E. Let it be firmly supported at L, B, C, M. Let it be cut through at A, and have compass-joints at B and C. Let FB, GC be two equal uprights, resting on B and C, but without any connection. Let AH be a similar and equal piece, to be occasionally applied at the seam A. Now let a thread or wire AGE be extended over the piece GC, and made fast at A, G, and E. Let the same thing be done on the other side of A. If a weight be now laid on at A, the wires AFD, AGE will be strained, and may be broken. In the instant of fracture we may suppose their strains to be represented by *Af* and *Ag*. Complete the parallelogram, and *Aa* is the magnitude of the weight. It is plain that nothing is concerned here but the cohesion of the wires; for the beam is sawed through at A, and its parts are perfectly moveable round B and C.

Instead of this process apply the piece AH below A, and keep it there by straining the same wire BHC over it. Now lay on a weight. It must press down the ends of BA and CA, and cause the piece AH to strain the wire BHC. In the instant of fracture of *the same* wire, its resistance *Hb* and *Hc* must be equal to *Af* and *Ag*, and the weight *bH* which breaks them must be equal to *Aa*.

Lastly, employ all the three pieces FB, AH, GC, with the same wire attached as before. There can be no doubt but that the weight which breaks all the four wires must be $= aA + b$, or twice *Aa*.

The reader cannot but see that the wires perform the very same office with the fibres of an entire beam LM held fast in the four holes D, B, C, and E, of some upright posts.

In the experiments for verifying this, by breaking slender bars of fine deal, we get complete demonstration, by measuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam simply laid on the props B and C: and there are many curious inferences to be made from these observations, but we have not room for them in this place.

We may observe, by the way, that we learn from this case, that purlins are able to carry twice the load when notched into the rafters that they carry when mortised into them, which is the most usual manner of framing them. So would the binding joists of floors; but this would double the thickness of the flooring. But this method should be followed in every possible case, such as breast summers, lintels over several pillars, &c. These should never be cut off and mortised into the sides of every upright; numberless cases will occur which shew the importance of the maxim.

We must here remark, that the proportion of the spaces BC and CM, or BC and LB, has a very sensible effect on the strength of the beam BC; but we have

not yet satisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the serpentine form of the curve of the beam before fracture. This should be attended to in the construction of the springs of carriages. These are frequently supported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the easiest motion to the body of the carriage. We also think that it is connected with that deviation from the best theory observable in Buffon's experiments on various lengths of the same scantling. The force of the beams diminished much more than in the inverse proportion of their lengths.

We have seen that it depends entirely on the position of the pieces in respect of their points of ultimate support, and of the direction of the external force which produces the strains, whether any particular piece is in a state of extension or of compression. The knowledge of this circumstance may greatly influence us in the choice of the construction. In many cases we may substitute slender iron rods for massive beams, when the piece is to act the part of a tie. But we must not invert this disposition; for when a piece of timber acts as a strut, and is in a state of compression, it is next to certain that it is not equally compressible in its opposite sides through the whole length of the piece, and that the compressing force on the abutting joint is not acting in the most equable manner all over the joint. A very trifling inequality in either of these circumstances (especially in the first) will compress the beam more on one side than on the other. This cannot be without the beam's bending, and becoming concave on that side on which it is most compressed. When this happens, the frame is in danger of being crushed, and soon going to ruin. It is therefore indispensably necessary to make use of beams in all cases where struts are required of considerable length, rather than of metal rods of slender dimensions, unless in situations where we can effectually prevent their bending, as in trussing a girder internally, where a cast iron strut may be firmly cased in it, so as not to bend in the smallest degree. In cases where the pressures are enormous, as in the very oblique struts of a centre or arch frame, we must be particularly cautious to do nothing which can facilitate the compression of either side. No mortises should be cut near to one side; no lateral pressure, even the slightest, should be allowed to touch it. We have seen a pillar of fir 12 inches long and one inch in section, when loaded with three tons, snap in an instant when pressed on one side by 16 pounds, while another bore 4½ tons without hurt, because it was inclosed (loosely) in a stout pipe of iron.

In such cases of enormous compression, it is of great importance that the compressing force bear equally on the whole abutting surfaces. The German carpenters are accustomed to put a plate of lead over the joint. This prevents, in some measure, the penetration of the end fibres. Mr Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the strut. By this contrivance the unavoidable change of form of the triangle made no partial bearing of either angle of the abutment. This always has a tendency to splinter off the heel of the beam where it presses strongest. It is a very judicious practice.

When circumstances allow it, we should rather employ

19
The best manner of framing purlins,

20
Ties are in general better than struts.

ploy ties than struts for securing a beam against lateral strains. When an upright pillar, such as a flag-staff, a mast, or the uprights of a very tall scaffolding, are to be shored up, the dependence is more certain on those braces that are stretched by the strain than on those which are compressed. The scaffolding of the iron bridge near Sunderland had some ties very judiciously disposed, and others with less judgment.

We should proceed to consider the transverse strains as they affect the various parts of a frame of carpentry; but we have very little to add to what has been said already in the article *STRENGTH of Materials* (Encycl.), and in the article *ROOF*. What we shall add in this article will find a place in our occasional remarks on different works. It may, however, be of use to recal to the reader's memory the following propositions.

21
General theorems concerning the relative strength of beams.

1. When a beam AB (fig. 15.) is firmly fixed at the end A, and a straining force acts perpendicularly to its length at any point B, the strain occasioned at any section C between B and A is proportional to CB, and may therefore be represented by the product $W \times CB$; that is, by the product of the number of tons, pounds, &c. which measure the straining force, and the number of feet, inches, &c. contained in CB. As the loads on a beam are easily conceived, we shall substitute this for any other straining force.

2. If the strain or load is uniformly distributed along any part of the beam lying beyond C (that is, further from A), the strain at C is the same as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

3. The strain on any section D of a beam AB (fig. 16.) resting freely on two props A and B, is $w \times \frac{AD \times DB}{AB}$ (see *ROOF*, n^o 19. and *STRENGTH of Materials*, n^o 92, &c. *Encycl.*) Therefore,

4. The strain on the middle point, by a force applied there, is one fourth of the strain which the same force would produce, if applied to one end of a beam of the same length, having the other end fixed.

5. The strain on any section C of a beam, resting on two props A and B, occasioned by a force applied perpendicularly to another point D, is proportional to the rectangle of the exterior segments, or is equal to $w \times \frac{AC \times DB}{AB}$. Therefore

The strain at C occasioned by the pressure on D, is the same with the strain at D occasioned by the same pressure on C.

6. The strain on any section D, occasioned by a load uniformly diffused over any part EF, is the same as if the two parts ED, DF of the load were collected at their middle points *e* and *f*. Therefore

The strain on any part D, occasioned by a load uniformly distributed over the whole beam, is one-half of the strain that is produced when the same load is laid on at D; and

The strain on the middle point C, occasioned by a load uniformly distributed over the whole beam, is the same which half that load would produce if laid on at C.

7. A beam supported at both ends on two props B and C (fig. 14.) will carry twice as much when the ends beyond the props are kept from rising, as it will carry when it rests loosely on the props.

8. Lastly, the transverse strain on any section, occasioned by a force applied obliquely, is diminished in the proportion of the sine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the strain is one half of the strain occasioned by the same force acting perpendicularly.

On the other hand, the *RELATIVE STRENGTH* of a beam, or its power in any particular section to resist any transverse strain, is proportional to the absolute cohesion of the section directly, to the distance of its centre of effort from the axis of fracture directly, and to the distance from the strained point inversely.

Thus in a rectangular section of the beam, of which *b* is the breadth, *d* the depth (that is, the dimension in the direction of the straining force), measured in inches, and *f* the number of pounds which one square inch will just support without being torn asunder, we must have $f \times b \times d^2$, proportional to $w \times CB$ (fig. 15.) Or, $f \times b \times d^2$, multiplied by some number *m*, depending on the nature of the timber, must be equal to $w \times CB$. Or, in the case of the section C of fig. 16. that is strained by the force *w* applied at D, we must have $m \times f b d^2 = w \times \frac{AC \times DB}{AB}$. Thus if the beam is of found oak, *m* is very nearly $= \frac{1}{9}$ (see *STRENGTH of Materials*, n^o 116. *Encycl.*) Therefore we have $\frac{f b d^2}{9} = w \times \frac{AC \times CB}{AB}$.

Hence we can tell the precise force *w* which any section C can just resist when that force is applied in any way whatever. For the above-mentioned formula gives $w = \frac{f b d^2}{9CB}$, for the case represented by fig. 15. But

the case represented in fig. 16. having the straining force applied at D, gives the strain at C ($= w$) $= f \times \frac{b d^2 \times AB}{9AC \times CB}$.

Example. Let an oak beam, four inches square, rest freely on the props A and B, seven feet apart, or 84 inches. What weight will it just support at its middle point C, on the supposition that a square inch rod will just carry 16,000 pounds, pulling it asunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84}{86016000}$, or $w = \frac{15876}{15876} = 5418$ pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the straining force acted on a point D, half way between C and B, the force sufficient to break the beam at C would be $= \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} = 10836$ lbs.

Had the beam been found red fir, we must have taken *f* = 10,000 nearly, and *m* nearly 8; for although fir be less cohesive than oak in the proportion of 5 to 8 nearly, it is less compressible, and its axis of fracture is therefore nearer to the concave side.

HAVING considered at sufficient length the strains of different kinds which arise from the form of the parts of a frame of carpentry, and the direction of the external forces which act on it, whether considered as impelling or as supporting its different parts, we must

now proceed to consider the means by which this form is to be secured, and the connections by which those strains are excited and communicated.

The joinings practised in carpentry are almost infinitely various, and each has advantages which make it preferable in some circumstances. Many varieties are employed merely to please the eye. We do not concern ourselves with these: Nor shall we consider those which are only employed in connecting small works, and can never appear on a great scale: yet even in some of these, the skill of the carpenter may be discovered by his choice; for in all cases it is wise to make every, even the smallest, part of his work as strong as the materials will admit. He will be particularly attentive to the changes which will necessarily happen by the shrinking of timber as it dries, and will consider what dimensions of his framings will be affected by this, and what will not; and will then dispose the pieces which are less essential to the strength of the whole, in such a manner that their tendency to shrink shall be in the same direction with the shrinking of the whole framing. If he do otherwise, the seams will widen, and parts will be split asunder. He will dispose his boardings in such a manner as to contribute to the stiffness of the whole, avoiding at the same time the giving them positions which will produce lateral strains on truss beams which bear great pressures; recollecting, that although a single board has little force, yet many united have a great deal, and may frequently perform the office of very powerful struts.

Our limits confine us to the joinings which are most essential for connecting the parts of a single piece of a frame when it cannot be formed of one beam, either for want of the necessary thickness or length; and the joints for connecting the different sides of a trussed frame.

²³ Of building up beams. Much ingenuity and contrivance has been bestowed on the manner of building up a great beam of many thicknesses, and many singular methods are practised as great nostrums by different artists: but when we consider the manner in which the cohesion of the fibres performs its office, we will clearly see that the simplest are equally effectual with the most refined, and that they are less apt to lead us into false notions of the strength of the assemblage.

²⁴ Building up a girder or lever. Thus, were it required to build up a beam for a great lever or a girder, so that it may act nearly as a beam of the same size of one log—it may either be done by plain joggling, as in fig. 17. A, or by scarfing, as in fig. 17. B or C. If it is to act as a lever, having the gudgeon on the lower side at C, we believe that most artists will prefer the form B and C; at least this has been the case with nine-tenths of those to whom we have proposed the question. The best informed only hesitated; but the ordinary artists were all confident in its superiority; and we found their views of the matter very coincident. They consider the upper piece as grasping the lower in its hooks; and several imagined that, by driving the one very tight on the other, the beam would be stronger than an entire log: but if we attend carefully to the internal procedure in the loaded lever, we shall find the upper one clearly the strongest. If they are formed of equal logs, the upper one is thicker than the other by the depth of the jog-

gling or scarfing, which we suppose to be the same in both; consequently, if the cohesion of the fibres in the intervals is able to bring the uppermost filaments into full action, the form A is stronger than B, in the proportion of the greater distance of the upper filaments from the axis of the fracture: this may be greater than the difference of the thickness, if the wood is very compressible. If the gudgeon be in the middle, the effect, both of the joggles and the scarfings, is considerably diminished; and if it is on the upper side, the scarfings act in a very different way. In this situation, if the loads on the arms are also applied to the upper side, the joggled beam is still more superior to the scarfed one. This will be best understood by resolving it in imagination into a trussed frame. But when a gudgeon is thus put on that side of the lever which grows convex by the strain, it is usual to connect it with the rest by a powerful strap, which embraces the beam, and causes the opposite point to become the resisting point. This greatly changes the internal actions of the filaments, and, in some measure, brings it into the same state as the first, with the gudgeon below. Were it possible to have the gudgeon on the upper side, and to bring the whole into action without a strap, it would be the strongest of all; because, in general, the resistance to compression is greater than to extension. In every situation the joggled beam has the advantage; and it is the easiest executed.

We may frequently gain a considerable accession of strength by this building up of a beam; especially if the part which is stretched by the strain be of oak, and the other part be fir. Fir being so much superior to oak as a pillar (if Musschenbroek's experiments may be confided in), and oak so much preferable as a tie, this construction seems to unite both advantages. But we shall see much better methods of making powerful levers, girders, &c. by trussing.

Observe that the efficacy of both methods depends entirely on the difficulty of causing the piece between the cross joints to slide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as soon as they are so deep that their ends have a force sufficient to push the slice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings are frequently made oblique, as in fig. 18. but we imagine that this is a bad practice. It begins to yield at the point, where the wood is crippled and splintered off, or at least bruised out a little: as the pressure increases, this part, by squeezing broader, causes the solid parts rise to a little upwards, and gives them some tendency, not only to push their antagonists along the base, but even to tear them up a little. For similar reasons, we disapprove of the favourite practice of many artists, to make the angles of their scarfings acute, as in fig. 19. This often causes the two pieces to tear each other up. The abutments should always be perpendicular to the directions of the pressures. Lest it should be forgotten in its proper place, we may extend this injunction also to the abutments of different pieces of a frame, and recommend it to the artist even to attend to the shrinking of the timbers by drying. When two timbers abut obliquely, the joint should be most full

full at the obtuse angle of the end; because, by drying, that angle grows more obtuse, and the beam would then be in danger of splintering off at the acute angle.

It is evident that the nicest work is indispensably necessary in building up a beam. The parts must abut on each other completely, and the smallest play or void takes away the whole efficacy. It is usual to give the butting joints a small taper to one side of the beam, so that they may require moderate blows of a maul to force them in, and the joints may be perfectly close when the external surfaces are even on each side of the beam. But we must not exceed in the least degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a state of violent strain, and the abutments are perhaps ready to splinter off by a small addition of pressure. This is like too severe a proof for artillery; which, though not sufficient to burst the pieces, has weakened them to such a degree, that the strain of ordinary service is sufficient to complete the fracture. The workman is tempted to exceed in this, because it smooths off and conceals all uneven seams; but he must be watched. It is not unusual to leave some abutments open enough to admit a thin wedge reaching through the beam. Nor is this a bad practice, if the wedge is of materials which is not compressed by the driving or the strain of service. Iron would be preferable for this purpose, and for the joggles, were it not that by its too great hardness it cripples the fibres of timber to some distance. In consequence of this, it often happens that, in beams which are subjected to defultory and sudden strains (as in the levers of reciprocating engines), the joggles or wedges widen the holes, and work themselves loose: Therefore skilful engineers never admit them, and indeed as few bolts as possible, for the same reason: but when resisting a steady or dead pull, they are not so improper, and are frequently used.

Beams are built up not only to increase their dimensions in the direction of the strain (which we have hitherto called their depth), but also to increase their breadth or the dimensions perpendicular to the strain. We sometimes double the breadth of a girder which is thought too weak for its load, and where we must not increase the thickness of the flooring. The mast of a great ship of war must be made bigger athwartship, as well as fore and aft. This is one of the nicest problems of the art; and professional men are by no means agreed in their opinions about it. We do not presume to decide; and shall content ourselves with exhibiting the different methods.

The most obvious and natural method is that shewn in fig. 20. It is plain that (independent of the connection of cross bolts, which are used in them all when the beams are square) the piece C cannot bend in the direction of the plane of the figure without bending the piece D along with it. This method is much used in the French navy; but it is undoubtedly imperfect. Hardly any two great trees are of equal quality, and swell and shrink alike. If C shrinks more than D, the feather of C becomes loose in the groove wrought in D to receive it; and when the beam bends, the parts can slide on each other like the plates of a coach spring; and if the bending is in the direction *ef*, there is nothing to hinder this sliding but the bolts, which soon work themselves loose in the bolt-holes.

Fig. 21. exhibits another method. The two halves of the beam are tabled into each other in the same manner as in fig. 17. It is plain that this will not be affected by the unequal swelling or shrinking, because this is insensible in the direction of the fibres; but when bent in the direction *ab*, the beam is weaker than fig. 20. bent in the direction *ef*. Each half of fig. 20. has, in every part of its length, a thickness greater than half the thickness of the beam. It is the contrary in the alternate portions of the halves of fig. 21. When one of them is bent in the direction AB, it is plain that it drags the other with it by means of the cross buttments of its tables, and there can be no longitudinal sliding. But unless the work is accurately executed, and each hollow completely filled up by the table of the other piece, there will be a lateral slide along the cross joints sufficient to compensate for the curvature; and this will hinder the one from compressing or stretching the other in conformity to this curvature.

The imperfection of this method is so obvious, that it has seldom been practised: but it has been combined with the other, as is represented in fig. 22. where the beams are divided along the middle, and the tables in each half are alternate, and alternate also with the tables of the other half. Thus 1, 3, 4, are prominent, and 5, 2, 6, are depressed. This construction evidently puts a stop to both sides, and obliges every part of both pieces to move together. *ab* and *cd* show sections of the built-up beam corresponding to AB and CD.

No more is intended in this practice by any intelligent artist, than the causing the two pieces to act together in all their parts, although the strains may be unequally distributed on them. Thus, in a built-up girder, the binding joints are frequently mortised into very different parts of the two sides. But many seem to aim at making the beam stronger than if it were of one piece; and this inconsiderate project has given rise to many whimsical modes of tabling and scarfing, which we need not regard.

The practice in the British dock-yards is somewhat different from any of these methods. The pieces are tabled as in fig. 22. but the tables are not thin parallelepipeds, but thin prisms. The two outward joints or visible seams are straight lines, and the table *n^o 1.* rises gradually to its greatest thickness in the axis. In like manner, the hollow *5.* for receiving the opposite table, sinks gradually from the edge to its greatest depth in the axis. Fig. 23. represents a section of a round piece of timber built up in this way, where the full line EFGH is the section corresponding to AB of fig. 22. and the dotted line EGFH is the section corresponding to CD.

This construction, by making the external seam straight, leaves no lodgment for water, and looks much fairer to the eye: but it appears to us that it does not give such firm hold when the mast is bent in the direction EH. The exterior parts are most stretched and most compressed by this bending; but there is hardly any abutment in the exterior parts of these tables. In the very axis, where the abutment is the firmest, there is little or no difference of extension and compression.

But this construction has an advantage, which we imagine much more than compensates for these imperfections,

26
We must not wedge too hard.

29
Another method.

30
Its imperfection.

37
British method;

27
Building of masts.

28
Method used in the French Navy.

fections, at least in the particular case of a round mast: it will draw together by hooping incomparably better than any of the others. If the cavity be made somewhat too shallow for the prominence of the tables, and if this be done uniformly along the whole length, it will make a somewhat open seam; and this opening can be regulated with the utmost exactness from end to end by the plane. The heart of those vast trunks is very sensibly softer than the exterior circles: Therefore, when the whole is hooped, and the hoops hard driven, and at considerable intervals between each spell—we are confident that all may be compressed till the seam disappears; and then the whole makes one piece, *much* stronger than if it were an original log of that size; because the middle has become, by compression, as solid as the crust, which was naturally firmer, and resisted farther compression. We verified this beyond a doubt, by hooping a built stick of a timber which has this inequality of firmness in a remarkable degree, and it was nearly twice as strong as another of the same size.

Our malmakers are not without their fancies and whims; and the manner in which our masts and yards are generally built up, is not near so simple as fig. 22.: but it consists of the same essential parts, acting in the very same manner, and derives all its efficacy from the principles which are here employed.

This construction is particularly suited to the situation and office of a ship's mast. It has no bolts; or, at least, none of any magnitude, or that make very important parts of its construction. The most violent strains perhaps that it is exposed to, is that of twisting, when the lower yards are close braced up by the force of many men acting by a long lever. This form resists a twist with peculiar energy: it is therefore an excellent method for building up a great shaft for a mill. The way in which they are usually built up is by reducing a central log to a polygonal prism, and then filling it up to the intended size by *planting* pieces of timber along its sides, either spiking them down, or cocking them into it by a feather, or joggling them by slips of hard wood sunk into the central log and into the slips. *N. B.* Joggles of elm are sometimes used in the middle of the large tables of masts; and when sunk into the firm wood near the surface, they must contribute much to the strength. But it is very necessary to employ wood not much harder than the pine; otherwise it will soon enlarge its bed, and become loose; for the timber of these large trunks is very soft.

The most general reason for piecing a beam is to increase its length. This is frequently necessary, in order to procure tie-beams for very wide roofs. Two pieces must be scarfed together.—Numberless are the modes of doing this; and almost every master carpenter has his favourite nostrum. Some of them are very ingenious: But here, as in other cases, the most simple are commonly the strongest. We do not imagine that any, the most ingenious, is equally strong with a tie consisting of two pieces of the same scantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artless and clumsy tie-beam; but we only say that it will be stronger than any that is more artificially made up of the same thickness of timber. This, we imagine, will appear sufficiently certain.

The simplest and most obvious scarfing (after the

one now mentioned) is that represented in fig. 24. n° 1. and 2. If considered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the strength of an entire piece, supposing that the bolts (which are the only connections) are fast in their holes. N° 2. requires a bolt in the middle of the scarf to give it that strength; and, in every other part, is weaker on one side or the other.

But the bolts are very apt to bend by the violent strain, and require to be strengthened by uniting their ends by iron plates; in which case it is no longer a wooden tie. The form of n° 1. is better adapted to the office of a pillar than n° 2.; especially if its ends be formed in the manner shewn in the elevation n° 3. By the sally given to the ends, the scarf resists an effort to bend it in that direction. Besides, the form of n° 2. is unsuitable for a post; because the pieces, by sliding on each other by the pressure, are apt to splinter off the tongue which confines their extremity.

Fig. 25. and 26. exhibit the most approved form of a scarf, whether for a tie or for a post. The key represented in the middle is not essentially necessary; the two pieces might simply meet square there. This form, without a key, needs no bolts (although they strengthen it greatly); but, if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightness. The same precaution must be observed that we mentioned on another occasion, not to produce a constant internal strain on the parts by overdriving the key. The form of fig. 25. is by far the best; because the triangle of 26. is much easier splintered off by the strain, or by the key, than the square wood of 25. It is far preferable for a post, for the reason given when speaking of fig. 24. n° 1. and n° 2. Both may be formed with a sally at the ends equal to the breadth of the key. In this shape, fig. 25. is vastly well suited for joining the parts of the long corner posts of spires and other wooden towers. Fig. 25. n° 2. differs from n° 1. only by having three keys. The principle and the longitudinal strength are the same. The long scarf of n° 2. tightened by the three keys, enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third, it has less than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the simple form of fig. 24. n° 1. is stronger than those more ingenious scarfings. It may be strengthened against lateral bending by a little tongue, or by a sally; but it cannot have both.

The strongest of all methods of piecing a tie-beam would be to set the parts end to end, and grasp them between other pieces on each side, as in fig. 27. This is what the ship-carpenter calls *fishing* a beam; and is a frequent practice for occasional repairs. Mr Perronet used it for the tie-beams or stretchers, by which he connected the opposite feet of a centre, which was yielding to its load, and had pushed aside one of the piers above four inches. Six of these not only withstood a strain of 1800 tons, but, by wedging behind them, he

brought

32
Attended
with peculiar
advantages.

33
Various
methods of
scarfing.

34
Fishing a
beam.

brought the feet of the trufs $2\frac{1}{2}$ inches nearer. The stretchers were 14 inches by 11 of found oak, and could have withstood three times that strain. Mr Perronet, fearing that the great length of the bolts employed to connect the beams of these stretchers would expose them to the risk of bending, scarfed the two side pieces into the middle piece. The scarfing was of the triangular kind (*Traité de Jupiter*), and only an inch deep, each face being two feet long, and the bolt passed through close to the angle.

In piecing the pump rods, and other wooden stretchers of great engines, no dependence is had on scarfing; and the engineer connects every thing by iron straps. We doubt the propriety of this, at least in cases where the bulk of the wooden connection is not inconvenient. These observations must suffice for the methods employed for connecting the parts of a beam; and we now proceed to consider what are more usually called the joints of a piece of carpentry.

Where the beams stand square with each other, and the strains are also square with the beams, and in the plane of the frame, the common mortise and tenon is the most perfect junction. A pin is generally put through both, in order to keep the pieces united, in opposition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, so that it shall draw the tenon tight into the mortise, and cause the shoulder to butt close, and make neat work; and he knows the risk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may just observe, that square holes and pins are much preferable to round ones for this purpose, bringing more of the wood into action, with less tendency to split it. The ship carpenters have an ingenious method of making long wooden bolts, which do not pass completely through, take a very fast hold, though not nicely fitted to their holes, which they must not be, lest they should be crippled in driving. They call it *foxtail wedging*. They stick into the point of the bolt a very thin wedge of hard wood, so as to project a proper distance; when this reaches the bottom of the hole by driving the bolt, it splits the end of it, and squeezes it hard to the side. This may be practised with advantage in carpentry. If the ends of the mortise are widened inwards, and a thin wedge be put into the end of the tenon, it will have the same effect, and make the joint equal to a dovetail. But this risks the splitting the piece beyond the shoulder of the tenon, which would be unsightly. This may be avoided as follows: Let the tenon T, fig. 28. have two very thin wedges *a* and *c* stuck in near its angles, projecting equally; at a very small distance within these, put in two shorter ones *b*, *d*, and more within these if necessary. In driving this tenon, the wedges *a* and *c* will take first, and split off a thin slice, which will easily bend without breaking. The wedges *b*, *d*, will act next, and have a similar effect, and the others in succession. The thickness of all the wedges taken together must be equal to the enlargement of the mortise toward the bottom.

When the strain is transverse to the plane of the two beams, the principles laid down in n° 85, 86. of the article *STRENGTH of Materials*, will direct the artist in placing his mortise. Thus the mortise in a girder for receiving the tenon of a binding joist of a floor should

be as near the upper side as possible, because the girder becomes concave on that side by the strain. But as this exposes the tenon of the binding joist to the risk of being torn off, we are obliged to mortise farther down. The form (fig. 29.) generally given to this joint is extremely judicious. The sloping part *ab* gives a very firm support to the additional bearing *ed*, without much weakening of the girder. This form should be copied in every case where the strain has a similar direction.

The joint that most of all demands the careful attention of the artist, is that which connects the ends of beams, one of which pushes the other very obliquely, putting it into a state of extension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam, and thereby *drawing* it away from the other wall. When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a small distance beyond the foot of the rafter: but, indeed, the dimensions which are given to tie-beams, for other reasons, are always sufficient to give enough of abutment when judiciously employed. Unfortunately this joint is much exposed to failure by the effects of the weather. It is much exposed, and frequently perishes by rot, or becomes so soft and friable that a very small force is sufficient, either for pulling the filaments out of the tie-beam, or for crushing them together. We are therefore obliged to secure it with particular attention, and to avail ourselves of every circumstance of construction.

One is naturally disposed to give the rafter a deep hold by a long tenon; but it has been frequently observed in old roofs that such tenons break off. Frequently they are observed to tear up the wood that is above them, and push their way through the end of the tie-beam. This, in all probability, arises from the first sagging of the roof, by the compression of the rafters and of the head of the king-post. The head of the rafter descends, the angle with the tie-beam is diminished by the rafter revolving round its step in the tie-beam. By this motion the heel or inner angle of the rafter becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very short, and being still fresh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortise, and then pushes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a shape which abuts firmly, in the direction of the thrust, on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form has the farther advantage of having no tendency to tear up the end of the mortise. This form is represented in fig. 30. The tenon has a small portion *ab* cut perpendicular to the surface of the tie-beam, and the rest *bc* is perpendicular to the rafter.

But if the tenon is not sufficiently strong (and it is not so strong as the rafter, which is thought not to be stronger than is necessary), it will be crushed, and then the rafter will slide out along the surface of the beam. It is therefore necessary to call in the assistance of the whole

37
Oblique mortise and tenon.

35
square joints.

36
foxtail wedging.

whole rafter. It is in this distribution of the strain among the various abutting parts that the varieties of joints and their merits chiefly consist. It would be endless to describe every no^oum, and we shall only mention a few that are most generally approved of.

38
Most ap-
proved
forms.

The aim in fig. 31. is to make the abutments exactly perpendicular to the thrusts. It does this very precisely; and the share which the tenon and the shoulder have of the whole may be what we please, by the portion of the beam that we notch down. If the wall-plate lie duly before the heel of the rafter, there is no risk of straining the tie across or breaking it, because the thrust is made direct to that point where the beam is supported. The action is the same as against the joggle on the head or foot of a king-post. We have no doubt but that this is a very effectual joint. It is not, however, much practised. It is said that the sloping seam at the shoulder lodges water; but the great reason seems to be a secret notion that it weakens the tie-beam. If we consider the direction in which it acts as a tie, we must acknowledge that this form takes the best method for bringing the whole of it into action.

Fig. 32. exhibits a form that is more general, but certainly worse. What part of the thrust that is not borne by the tenon acts obliquely on the joint of the shoulder, and gives the whole a tendency to rise up and slide outward.

The shoulder joint is sometimes formed like the dotted line *abcdefg* of fig. 32. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals *bd* and *df* are so short that the little wooden triangles *bcd*, *def*, will be easily pushed off their bases *bd*, *df*.

Fig. 33. seems to have the most general approbation. It is the joint recommended by Price (page 7.), and copied into all books of carpentry as the *true joint* for a rafter foot. The visible shoulder-joint is flush with the upper surface of the tie-beam. The angle of the tenon at the tie nearly bisects the obtuse angle formed by the rafter and the beam, and is therefore somewhat oblique to the thrust. The inner shoulder *ac* is nearly perpendicular to *bd*. The lower angle of the tenon is cut off horizontally as at *ed*. Fig. 34. is a section of the beam and rafter foot, shewing the different shoulders.

We do not perceive the peculiar merit of this joint. The effect of the three oblique abutments *ab*, *ac*, *ed*, is undoubtedly to make the whole bear on the outer end of the mortise, and there is no other part of the tie-beam that makes immediate resistance. Its only advantage over a tenon extending in the direction of the thrust is, that it will not tear up the wood above it. Had the inner shoulder had the form *eci*, having its face *ic* perpendicular, it would certainly have acted more powerfully in stretching many filaments of the tie-beam, and would have had much less tendency to force out the end of the mortise. The little bit *ci* would have prevented the sliding upwards along *ec*. At any rate, the joint *ab* being flush with the beam, prevents any sensible abutment on the shoulder *ac*.

Fig. 33. n^o 2. is a simpler, and in our opinion a preferable, joint. We observe it practised by the most eminent carpenters for all oblique thrusts; but it surely employs less of the cohesion of the tie-beam than might be used without weakening it, at least when it is supported on the other side by the wall-plate.

Fig. 33. n^o 3. is also much practised by the first carpenters.

Fig. 35. is proposed by Mr Nicholson (page 65.) as preferable to fig. 33. n^o 3. because the abutment of the inner part is better supported. This is certainly the case; but it supposes the whole rafter to go to the bottom of the socket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick; in which case they think that it requires a deeper socket than Nicholson has given it. Perhaps the advantages of Nicholson's construction may be had by a joint like fig. 35. n^o 2.

Whatever is the form of these butting joints, great care should be taken that all parts bear alike, and the artist will attend to the magnitude of the different surfaces. In the general compression, the greater surfaces will be less compressed, and the smaller will therefore change most. When all has settled, every part should be equally close. Because great logs are moved with difficulty, it is very troublesome to try the joint frequently to see how the parts fit; therefore we must expect less accuracy in the interior parts. This should make us prefer those joints whose efficacy depends chiefly on the visible joint.

It appears from all that we have said on this subject, that a very small part of the cohesion of the tie-beam is sufficient for withstanding the horizontal thrust of a roof, even though very low pitched. If therefore no other use is made of the tie-beam, one much slenderer may be used, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king-post. Although a tie-beam has commonly floors or ceilings to carry, and sometimes the workshops and store-rooms of a theatre, and therefore requires a great scantling, yet there frequently occur in machines and engines very oblique stretchers, which have no other office, and are generally made of dimensions quite inadequate to their situation, often containing ten times the necessary quantity of timber. It is therefore of importance to ascertain the most perfect manner of executing such a joint. We have directed the attention to the principles that are really concerned in the effect. In all hazardous cases, the carpenter calls in the assistance of iron straps; and they are frequently necessary, even in roofs, notwithstanding this superabundant strength of the tie-beam. But this is generally owing to bad construction of the wooden joint, or to the failure of it by time. Straps will be considered in their place.

There needs but little to be said of the joints at a joggle worked out of solid timber; they are not near so difficult as the last. When the size of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a square shoulder; or, which is still better, an arch of a circle, having the other end of the brace for its centre. Indeed this in general will not sensibly differ from a straight line perpendicular to the brace. By this circular form, the settling of the roof makes no change in the abutment; but when there is not sufficient stuff for this, we must avoid bevel joints at the shoulders, because these always tend to make the brace slide off. The brace in fig. 36. must not be joined as at *a*, but as at *b*, or some equivalent manner. Observe the joints at the

39
Circum-
stances to
be attend-
ed to.

the head of the main posts of Drury Line theatre, fig. D.

When the very oblique action of one side of a frame of carpentry does not extend but compress the piece on which it abuts (as in fig. 11.), there is no difficulty in the joint. Indeed a joining is unnecessary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that it do not produce lateral pressures, which may cause one of the pieces to slide on the butting joint. A very slight mortise and tenon is sufficient at the joggle of a king-post with a rafter or straining beam. It is best, in general, to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. In fig. 36. n^o 2. where the straining beam *ab* cannot slip away from the pressure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal pressures on the different parts, by which some are crippled, others are splintered off, &c.

When it is necessary to employ iron straps for strengthening a joint, a considerable attention is necessary, that we may place them properly. The first thing to be determined is the direction of the strain. This is learned by the observations in the beginning of this article. We must then resolve this strain into a strain parallel to each piece, and another perpendicular to it. Then the strap which is to be made fast to any of the pieces must be so fixed, that it shall resist in the direction parallel to the piece. Frequently this cannot be done; but we must come as near to it as we can. In such cases we must suppose that the assemblage yields a little to the pressures which act on it. We must examine what change of shape a small yielding will produce. We must now see how this will affect the iron strap which we have already supposed attached to the joint in some manner that we thought suitable. This settling will perhaps draw the pieces away from it, leaving it loose and unserviceable (this frequently happens to the plates which are put to secure the obtuse angles of butting timbers, when their bolts are at some distance from the angles, especially when these plates are laid on the inside of the angles); or it may cause it to compress the pieces harder than before; in which case it is answering our intention. But it may be producing cross strains, which may break them; or it may be crippling them. We can hardly give any general rules; but the reader will do well to read what is written in n^o 36. and 41. of the article ROOF, *Encycl.* In n^o 36. he will see the nature of the strap or stirrup, by which the king-post carries the tie-beam. The strap that we observe most generally ill placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, but does not act against its horizontal thrust. It should be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It should embrace the rafter almost horizontally near the foot, and should be notched square with the back of the rafter. Such a construction is represented in fig. 37. By moving round the eye-bolt, it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that straps which have eye-bolts in the very angles, and allow all motion round them, are of all the most perfect. A branched strap, such as may at once bind the king-post and the two

braces which butt on its foot, will be more serviceable if it have a joint. When a roof warps, those branched straps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artist will consider how the beams will act on such occasions, and will avoid giving rise to these great strains by levers.—A skilful carpenter never employs many straps, considering them as auxiliaries foreign to his art, and subject to imperfections in workmanship which he cannot discern nor amend. We must refer the reader to Nicholson's CARPENTER AND JOINER'S ASSISTANT for a more particular account of the various forms of stirrups, screwed rods, and other iron work for carrying tie-beams, &c.

As for those that are necessary for the turning joints of great engines constructed of timber, they make no part of the art of carpentry.

AFTER having attempted to give a systematic view of the principles of framing carpentry, we shall conclude, by giving some examples which will illustrate and confirm the foregoing principles.

Fig. 38. is the roof of the chapel of the Royal Hofpital at Greenwich, constructed by Mr S. Wyatt.

AA, Is the tie-beam, 57 feet long, spanning 51 feet clear	- - - - -	14 by 12
CC, Queen-posts	- - - - -	9x12
D, Braces	- - - - -	9x7
E, Truss beam	- - - - -	10x7
F, Straining piece	- - - - -	6x7
G, Principal rafters	- - - - -	10x7
H, A cambered beam for the platform	- - - - -	9-7
B, An iron string, supporting the tie-beam	- - - - -	2x2

The trusses are 7 feet apart, and the whole is covered with lead, the boarding being supported by horizontal ledgers *b, b*, of 6 by 4 inches.

This is a beautiful roof, and contains less timber than most of its dimensions. The parts are all disposed with great judgment. Perhaps the iron rod is unnecessary; but it adds great stiffness to the whole.

The iron straps at the rafter feet would have had more effect if not so oblique. Those at the head of the posts are very effective.

We may observe, however, that the joints between the straining beam and its braces are not of the best kind, and tend to bruise both the straining beam and the truss beam above it.

Fig. 39. the roof of St Paul's, Covent Garden, constructed by Mr Wapshot in 1796.

AA, Tie-beam spanning 50 feet 2 inches	- - - - -	16.12
B, Queen-post	- - - - -	9x8
C, Truss beam	- - - - -	10x8
D, King-post (14 at the joggle)	- - - - -	9x8
E, Brace	- - - - -	8x7½
FF, Principal brace (at bottom)	- - - - -	10x8½
HH, Principal rafter (at bottom)	- - - - -	10x8½
gg, Studs supporting the rafter	- - - - -	8x8

This roof far excels the original one put up by Inigo Jones. One of its trusses contains 198 feet of timber. One of the old roof had 273, but had many inactive timbers, and others ill disposed. (*N. B.* The figure which we gave of it in the article ROOF, copied from

CARPENTRY.

Price, is very erroneous). The internal truss FCF is admirably contrived for supporting the exterior rafters, without any pressure on the far projecting ends of the tie-beam. The former roof had bent them greatly, so as to appear ungraceful.

We think that the camber (six inches) of the tie-beam is rather hurtful; because, by settling, the beam lengthens; and this must be accompanied by a considerable sinking of the roof. This will appear by calculation.

45
Birmingham theatre.

Fig. 40. the roof of Birmingham theatre, constructed by Mr Geo. Saunders. The span is 80 feet clear, and the trusses are 10 feet apart.

A, Is an oak corbel	- - - -	9×5
B, Inner plate	- - - -	9×9
C, Wall plate	- - - -	8×5½
D, Pole plate	- - - -	7×5
E, Beam	- - - -	15×15
F, Straining beam	- - - -	12×9
G, Oak king-post (in the shaft)	- - - -	9×9
H, Oak queen-post (in the shaft)	- - - -	7×9
I, Principal rafters	- - - -	9×9
K, Common ditto	- - - -	4×2½
L, Principal braces	- - - -	9 and 6×9
M, Common ditto	- - - -	6×9
N, Purlins	- - - -	7×5
Q, Straining fill	- - - -	5½×9

This roof is a fine specimen of British carpentry, and is one of the boldest and lightest roofs in Europe. The straining fill Q gives a firm abutment to the principal braces, and the space between the posts is 19½ feet wide, affording roomy workshops for the carpenters and other workmen connected with a theatre. The contrivance for taking double hold of the wall, which is very thin, is excellent. There is also added a beam (marked R), bolted down to the tie-beams. The intention of this was to prevent the total failure of so bold a trussing, if any of the tie-beams should fail at the end by rot.

46
Drury Lane theatre.

Akin to this roof is fig. 41. the roof of Drury Lane theatre, 80 feet 3 inches in the clear, and the trusses 15 feet apart, constructed by Mr Edward Grey Saunders.

A, Beams	- - - -	10 by 7
B, Rafters	- - - -	7×7
C, King-posts	- - - -	12×7
D, Struts	- - - -	5×7
E, Purlins	- - - -	9×5
G, Pole plates	- - - -	5×5
I, Common rafters	- - - -	5×4
K, Tie-beam to the main truss	- - - -	15×12
L, Posts to ditto	- - - -	15×12
M, Principal braces to ditto	- - - -	14 and 12×12
N, Struts	- - - -	8×12
P, Straining beams	- - - -	12×12

The main beams are trussed in the middle space with oak trusses 5 inches square. This was necessary for its width of 32 feet, occupied by the carpenters, painters, &c. The great space between the trusses affords good store-rooms, dressing-rooms, &c.

It is probable that this roof has not its equal in the world for lightness, stiffness, and strength. The main truss is so judiciously framed, that each of them will safely bear a load of near 300 tons; so it is not likely that

they will ever be quarter loaded. The division of the whole into three parts makes the exterior roofings very light. The strains are admirably kept from the walls, and the walls are even firmly bound together by the roof. They also take off the dead weight from the main truss one-third.

47
Remarks.

The intelligent reader will perceive that all these roofs are on one principle, depending on a truss of three pieces and a straight tie-beam. This is indeed the great principle of a truss, and is a step beyond the roof with two rafters and a king post. It admits of much greater variety of forms, and of greater extent. We may see that even the middle part may be carried to any space, and yet be flat at top; for the truss beam may be supported in the middle by an inverted king-post (of timber, not iron), carried by iron or wooden ties from its extremities: And the same ties may carry the horizontal tie-beam K; for till K be torn asunder, or M, M, and P be crippled, nothing can fail.

The roof of St Martin's church in the Fields is constructed on good principles, and every piece properly disposed. But although its span does not exceed 40 feet from column to column, it contains more timber in a truss than there is in one of Drury-Lane theatre. The roof of the chapel at Greenwich, that of St Paul's, Covent Garden, that of Birmingham, and that of Drury Lane theatres, form a series gradually more perfect. Such specimens afford excellent lessons to the artists. We therefore account them a useful present to the public.

43
Project by

There is a very ingenious project offered to the public by Mr Nicholson (*Carpenter's Assistant*, p. 68.) He proposes iron rods for king-posts, queen-posts, and all other situations where beams perform the office of ties. This is in prosecution of the notions which we published in the article ROOF of the *Encycl.* (see n^o 36, 37.) He receives the feet of the braces and struts in a socket very well connected with the foot of his iron king-post; and he secures the feet of his queen-posts from being pushed inwards, by interposing a straining fill. He does not even mortise the foot of his principal rafter into the end of the tie-beam, but sets it in a socket like a shoe, at the end of an iron bar, which is bolted into the tie-beam a good way back. All the parts are formed and disposed with the precision of a person thoroughly acquainted with the subject; and we have not the smallest doubt of the success of the project, and the complete security and durability of his roofs, and we expect to see many of them executed. We abound in iron, but we must send abroad for building timber. This is therefore a valuable project; at the same time, however, let us not over-rate its value. Iron is but about 12 times stronger than red fir, and is more than 12 times heavier; nor is it cheaper, weight for weight, or strength for strength.

Our illustrations and examples have been chiefly taken from roofs, because they are the most familiar instances of the difficult problems of the art. We could have wished for more room even on this subject. The construction of dome roofs has been (we think) mistaken, and the difficulty is much less than is imagined. We mean in respect of strength; for we grant that the obliquity of the joints, and a general intricacy, increases the trouble of workmanship exceedingly. Another opportunity may perhaps occur for considering this subject.

Wooden

Fig. 1.

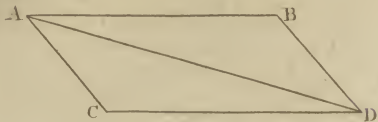


Fig. 2.

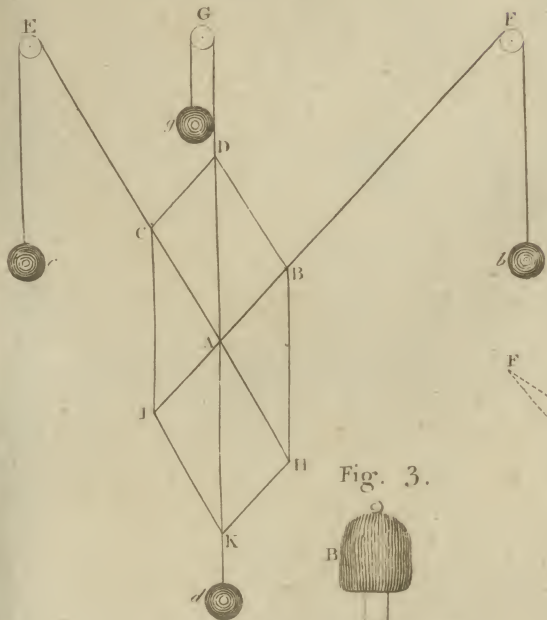


Fig. 3.

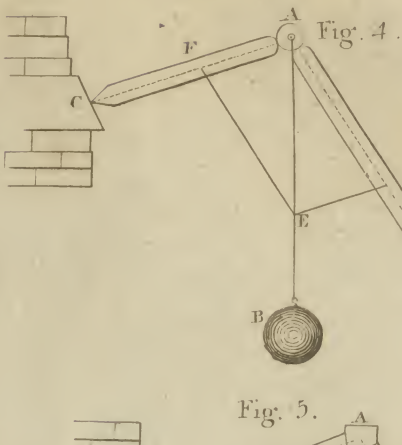


Fig. 5.

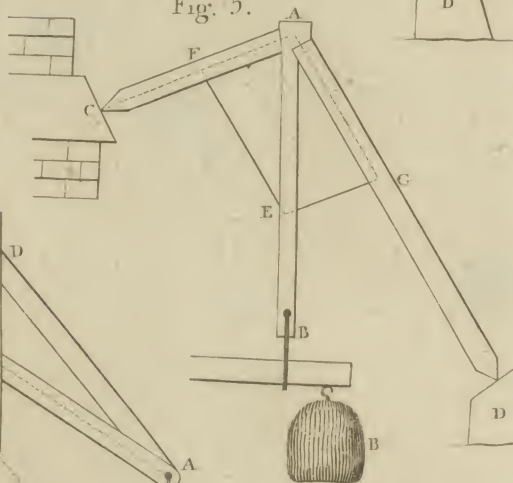


Fig. 8.

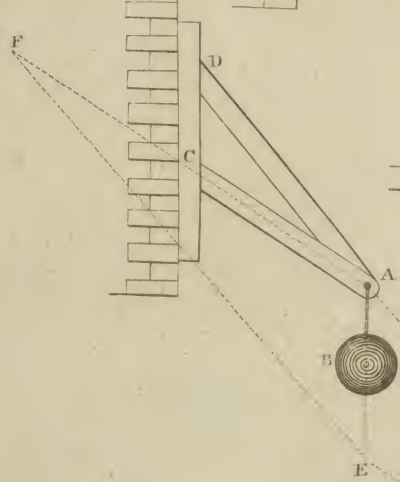


Fig. 6.

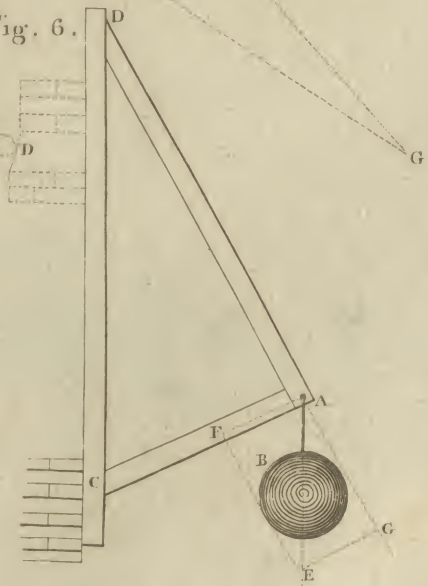


Fig. 7.

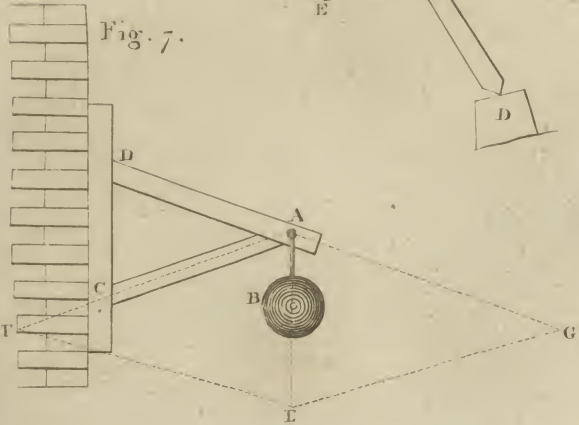


Fig. 10.

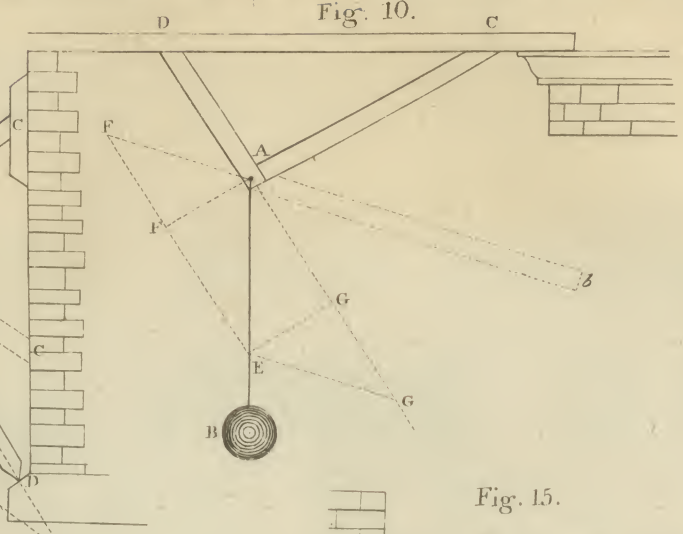


Fig. 9.

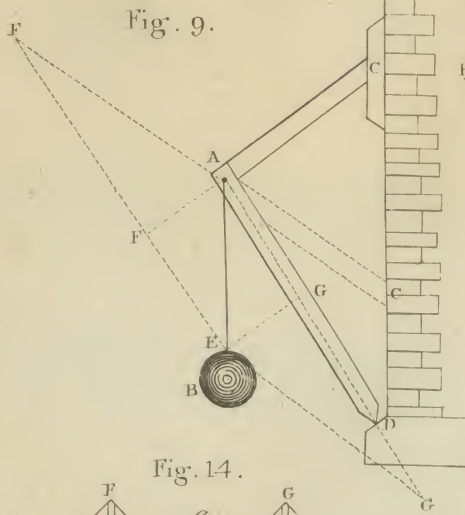


Fig. 15.

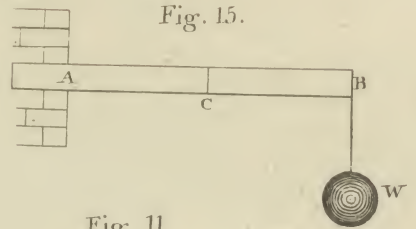


Fig. 14.

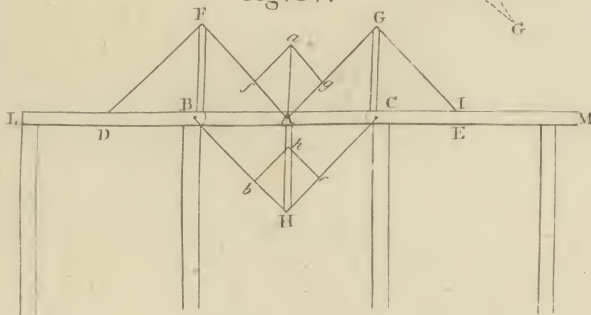


Fig. 11.

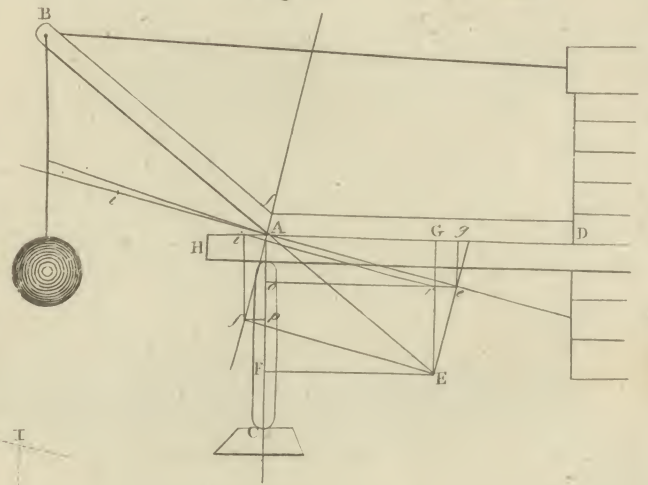


Fig. 12.

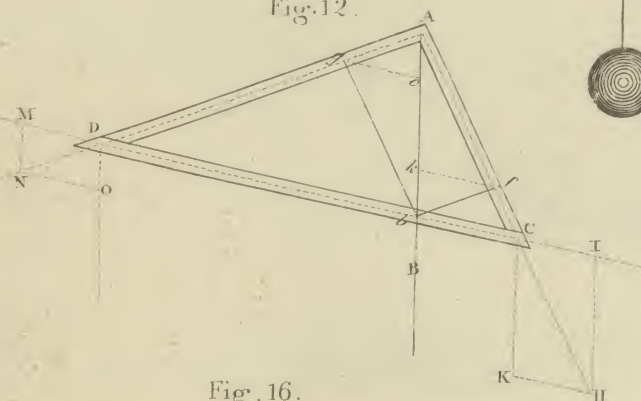


Fig. 16.

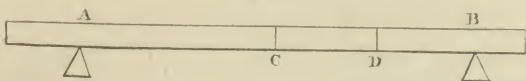


Fig. 13.

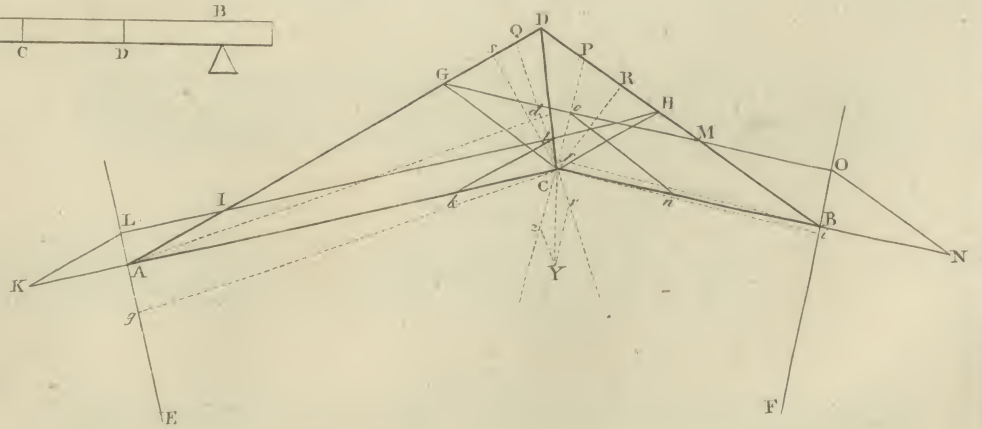


Fig. 17.



Fig. 18.



Fig. 19.



Fig. 22.

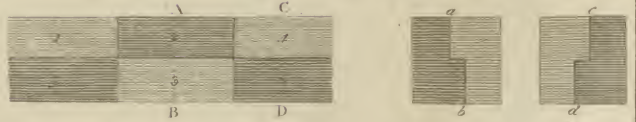


Fig. 21.

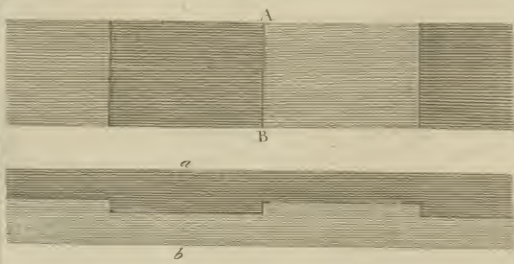


Fig. 23.

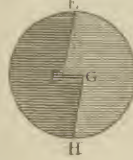


Fig. 23. N° 2.



Fig. 20.

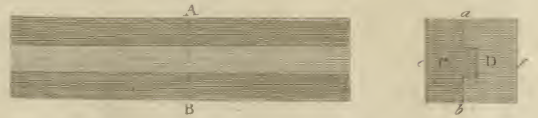


Fig. 24.



Fig. 24. N° 2.



Fig. 24. N° 3.

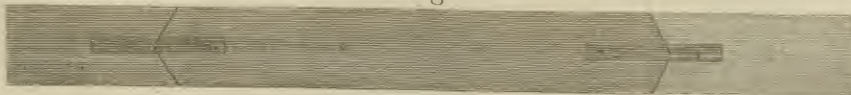


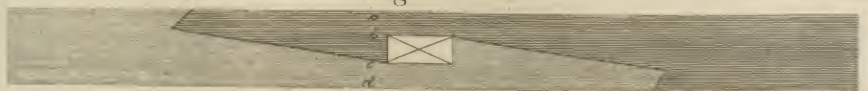
Fig. 25.



Fig. 25. N° 2.



Fig. 26.



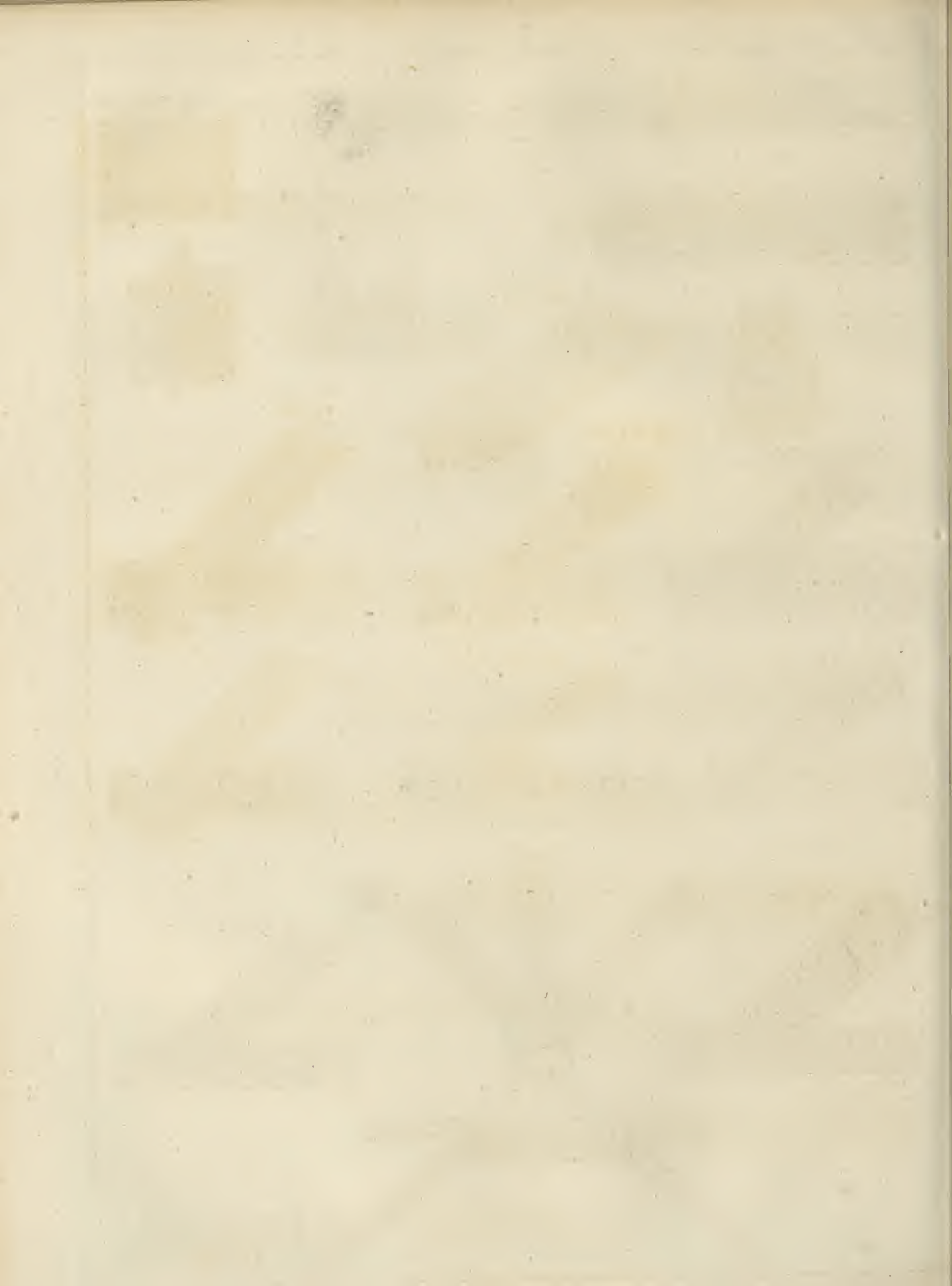


Fig. 27.



Fig. 29.



Fig. 28.



Fig. 34.

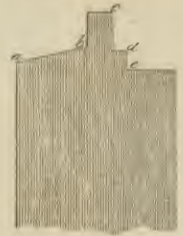


Fig. 33.

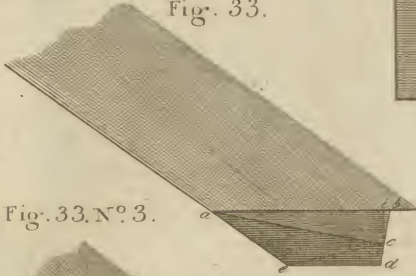


Fig. 30.

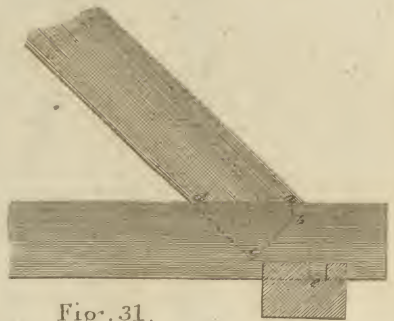


Fig. 33. N° 3.

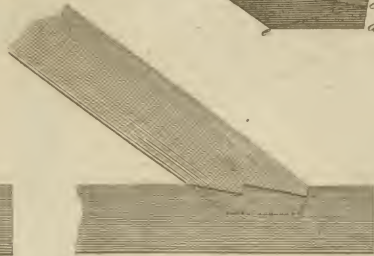


Fig. 33. N° 2.

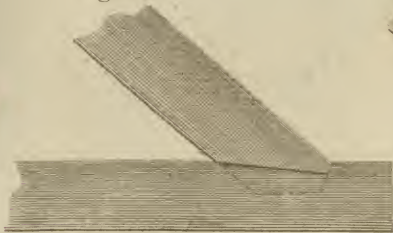


Fig. 31.

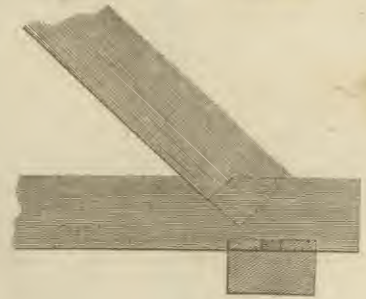


Fig. 32.

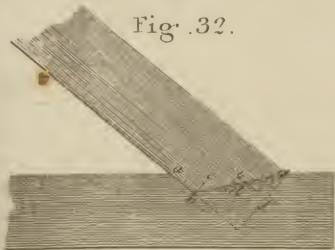


Fig. 37.

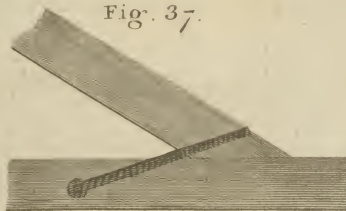


Fig. 36.

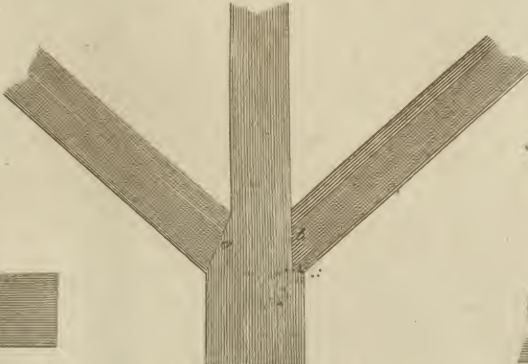


Fig. 35.

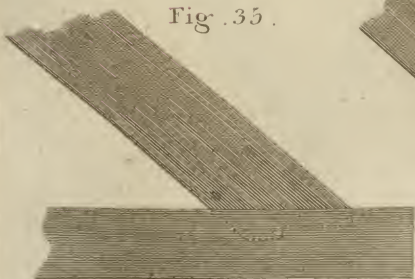


Fig. 35. N° 2.

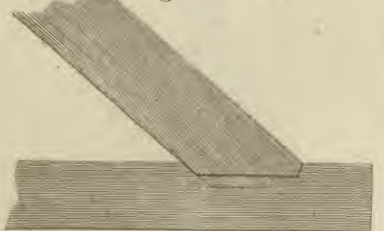
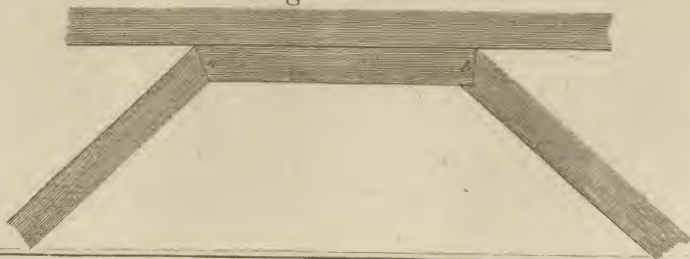


Fig. 36. N° 2.



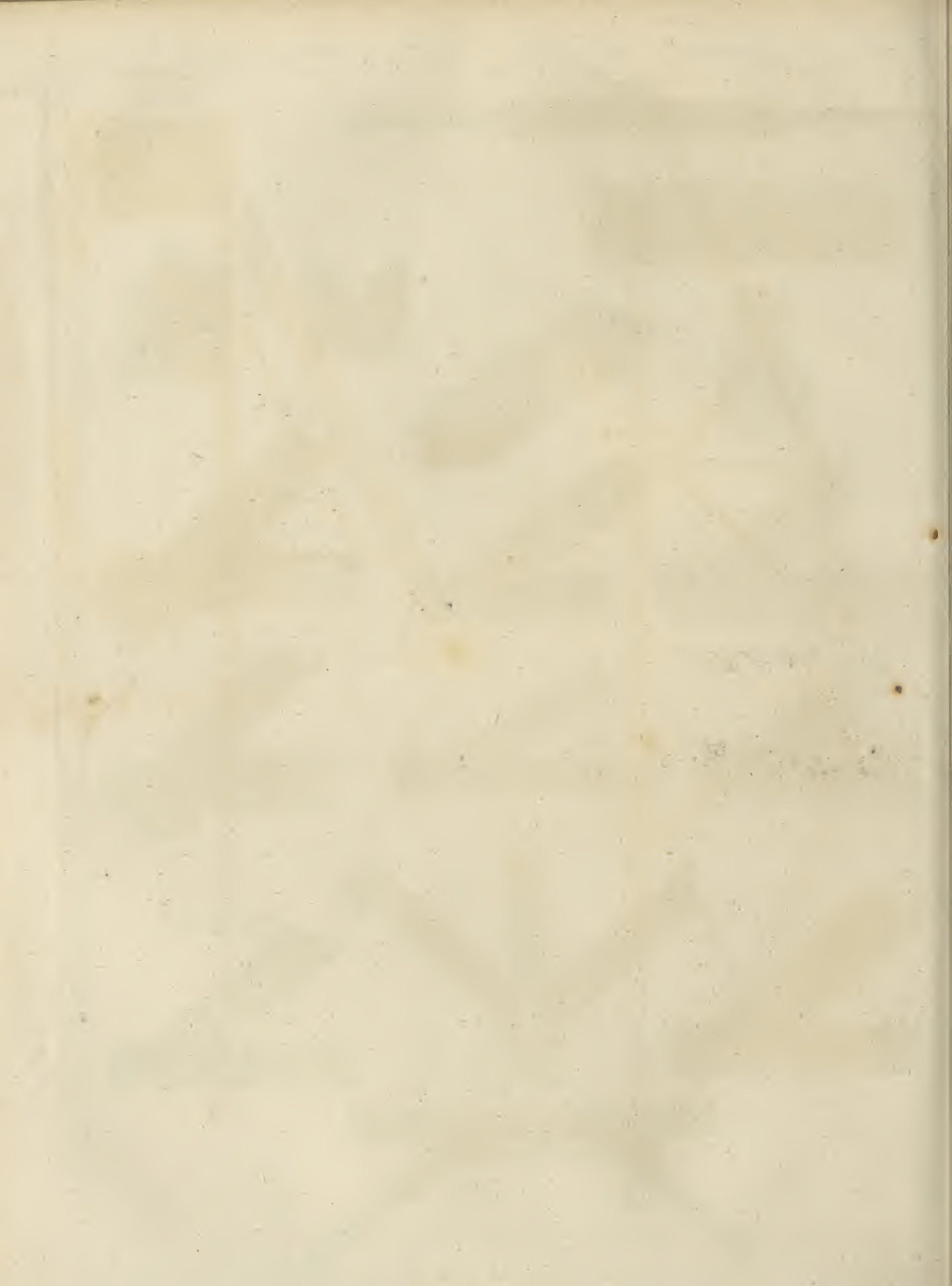


Fig. 38.

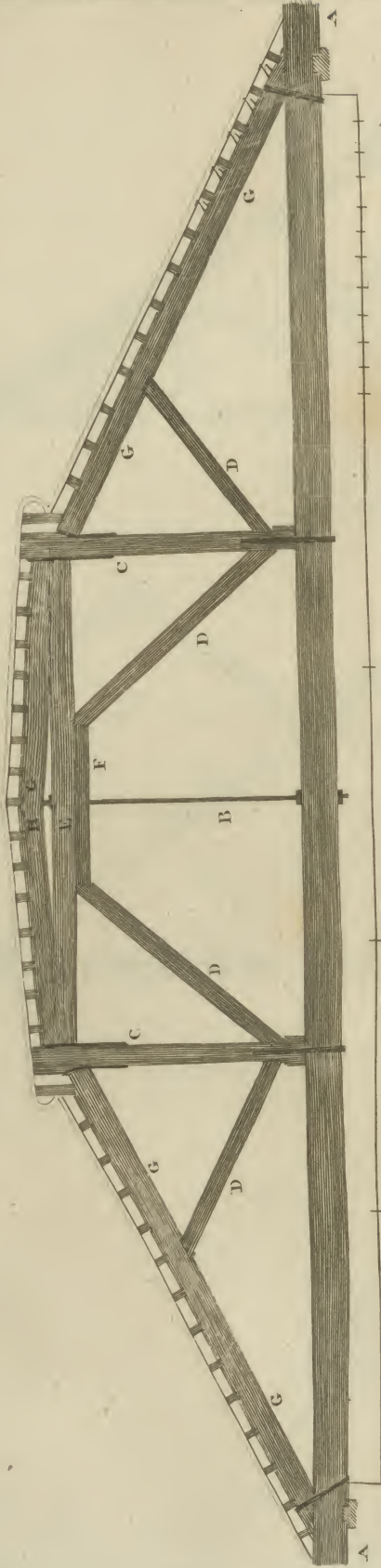
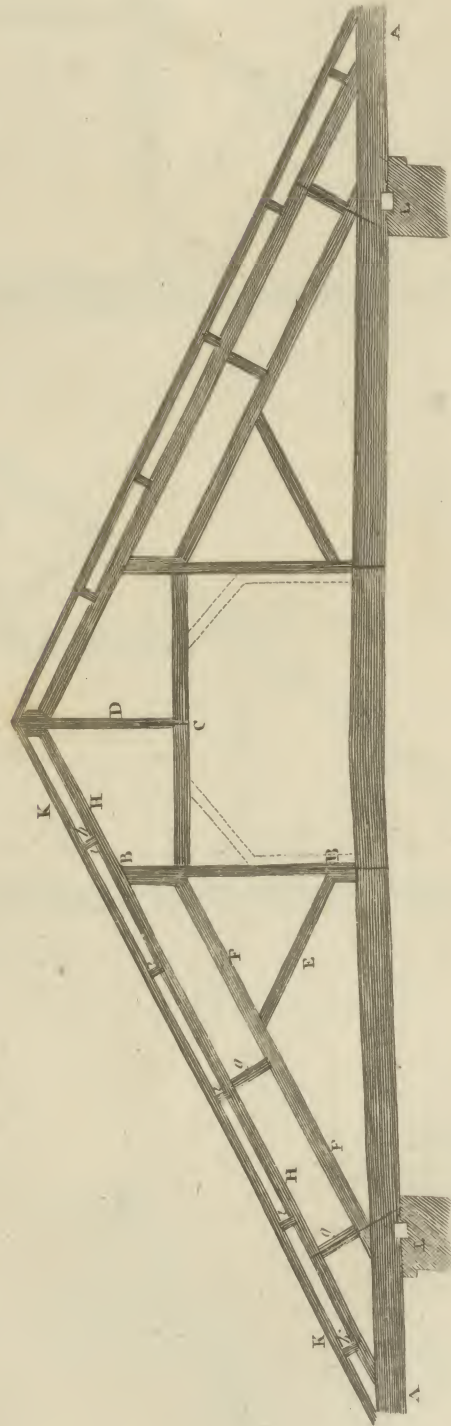


Fig. 39.



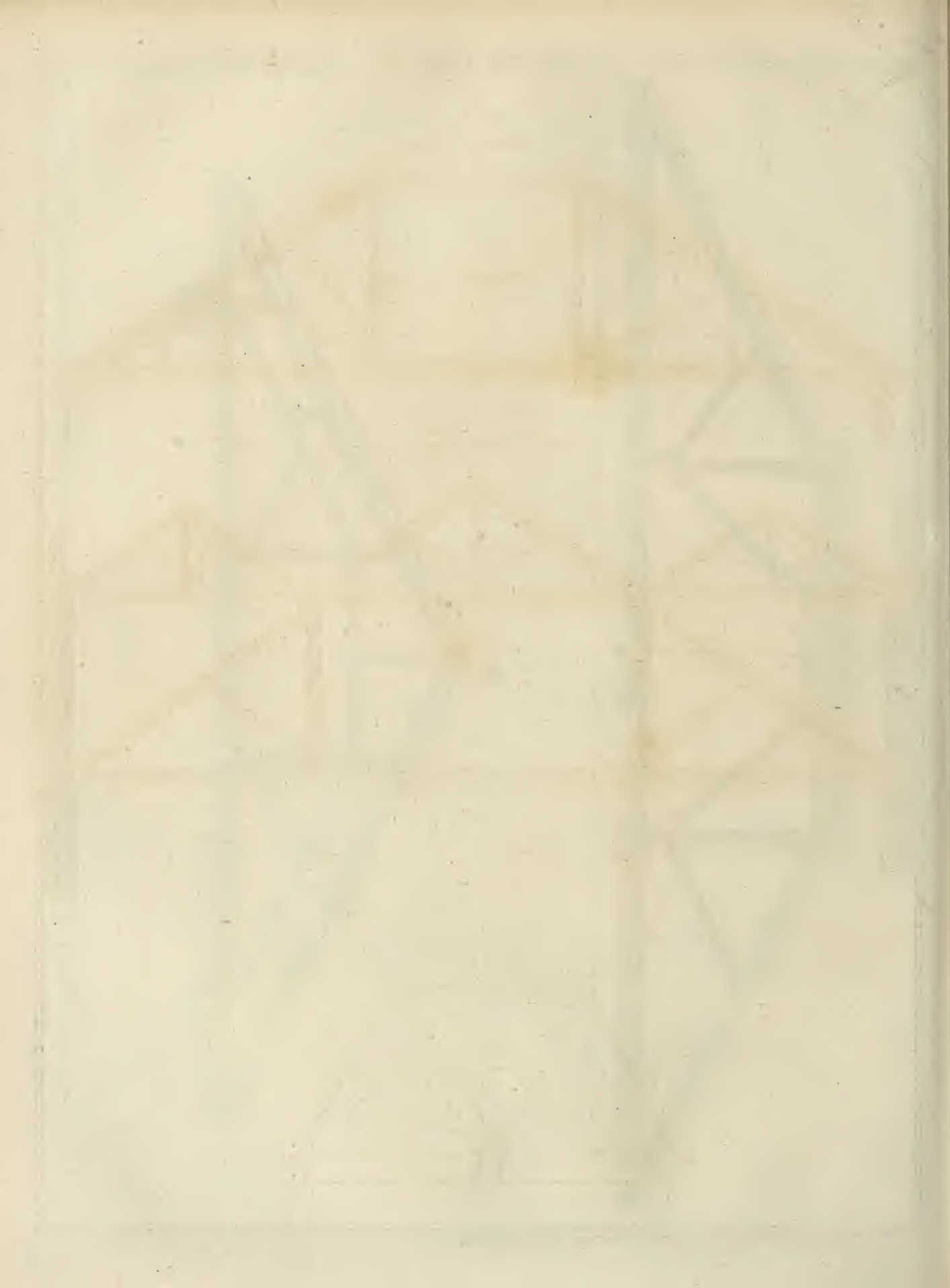
40 Feet

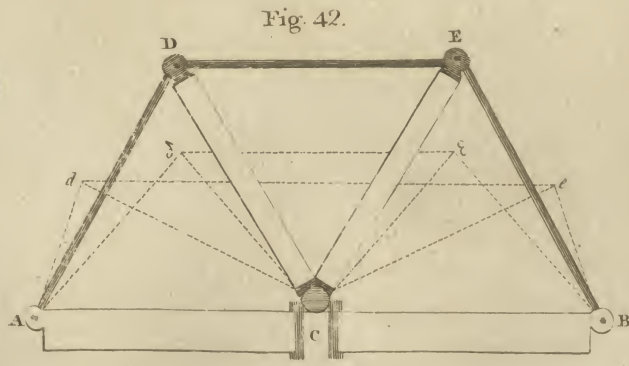
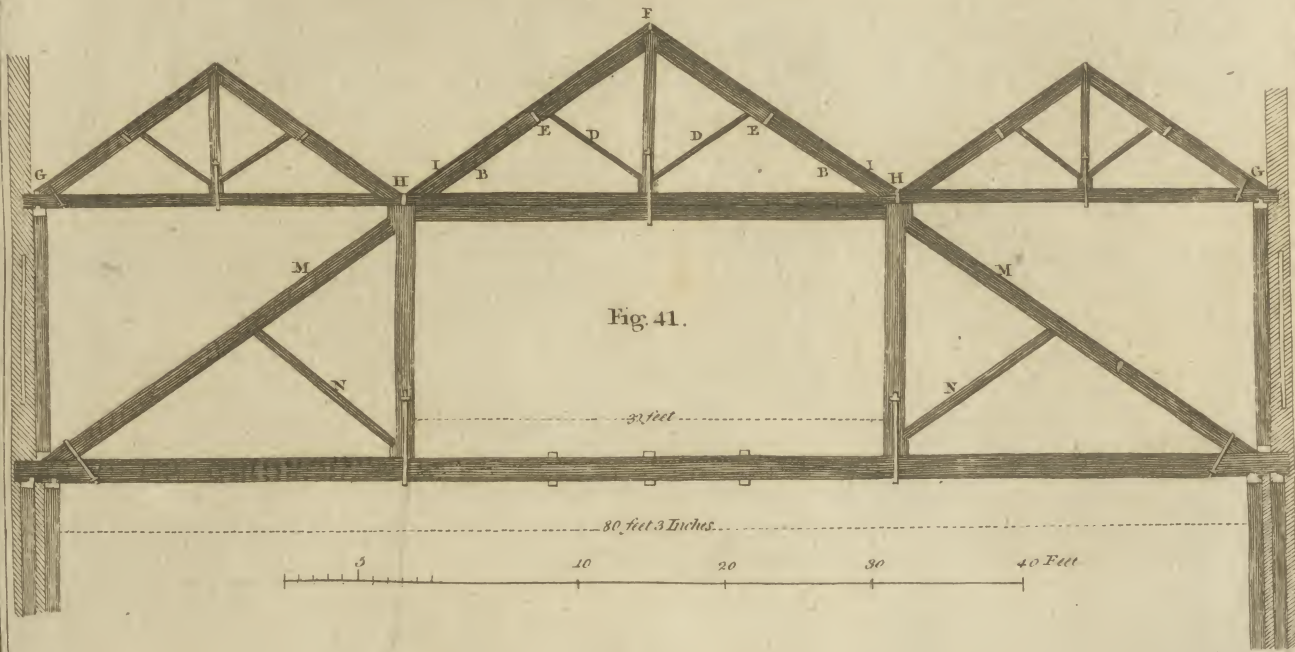
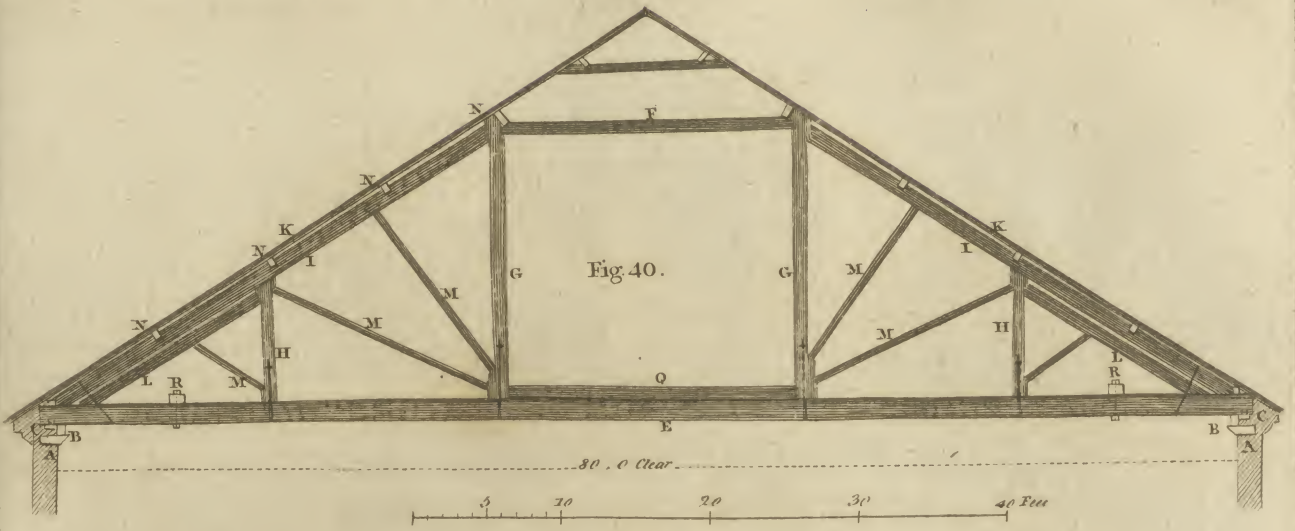
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Wooden bridges form another class equally difficult and important; but our limits are already overpassed, and will not admit them. The principle on which they should all be constructed, without exception, is that of a truss, avoiding all lateral bearings on any of the timbers. In the application of this principle, we must farther remark, that the angles of our truss should be as acute as possible; therefore we should make it of as few and as long pieces as we can, taking care to prevent the bending of the truss beams by bridges, which embrace them, but without pressing them to either side. When the truss consists of many pieces, the angles are very obtuse; and the thrusts increase nearly in the duplicate proportion of the number of angles. The proper maxims will readily occur to the artist who considers with attention the specimens of centres or coombs, which we shall give in the article CENTRE.

49
Wooden
bridges.

60
Framing of
great levers.

With respect to the frames of carpentry which occur in engines and great machines, the varieties are such that it would require a volume to treat of them properly. The principles are already laid down; and if the reader be really interested in the study, he will engage in it with seriousness, and cannot fail of being instructed. We recommend to his consideration, as a specimen of what may be done in this way, the working beam of Hornblower's steam-engine (see *STEAM-ENGINE*, n^o 84. *Encycl.*) When the beam must act by chains hung from the upper end of arch heads, the framing there given seems very scientifically constructed; at the same time, we think that a strap of wrought iron, reaching the whole length of the upper bar (see the figure), would be vastly preferable to those partial plates which the engineer has put there, for the bolts will soon work loose.

But when arches are not necessary, the form employed by Mr Watt is vastly preferable, both for simplicity and for strength. It consists of a simple beam AB (fig. 42.), having the gudgeon C on the upper side. The two piston-rods are attached to wrought iron joints

A and B. Two strong struts DC, EC rest on the upper side of the gudgeon, and carry an iron string ADEB, consisting of three pieces, connected with the struts by proper joints of wrought iron. A more minute description is not needed for a clear conception of the principle. No part of this is exposed to a cross strain; even the beam AB might be sawed through at the middle. The iron string is the only part which is stretched; for AC, DC, EC, BC, are all in a state of compression. We have made the angles equal, that all may be as great as possible, and the pressure on the struts and strings a minimum. Mr Watt makes them much lower, as $AdeB$, or $A^d e B$. But this is for economy, because the strength is almost insuperable. It might be made with wooden strings; but the workmanship of the joints would more than compensate the cheapness of the materials.

WE offer this article to the public with deference, and we hope for an indulgent reception of our essay on a subject which is in a manner new, and would require much study. We have bestowed our chief attention on the strength of the construction, because it is here that persons of the profession have the most scanty information. We beg them not to consider our observations as too refined, and that they will study them with care. One principle runs through the whole; and when that is clearly conceived and familiar to the mind, we venture to say that the practitioner will find it of easy application, and that he will improve every performance by a continual reference to it.

51
Conclusion.

If this attempt to instruct our most valuable and much esteemed artists shall appear to meet with their approbation, it may encourage us to engage in the serious task of composing a system on the subject. But this is a great work, and will require much time and liberal contribution of knowledge from the eminent carpenters who do honour to this country by their works.

C A S

CASCABEL, the knob or button of metal behind the breech of a cannon, as a kind of handle by which to elevate and direct the piece; to which some add the fillet and ogees as far as the base-ring.

Cascabel
||
Cassini.

CASEMATE, or CAZEMATE, in fortification, a kind of vault or arch of stone-work, in that part of the flank of a bastion next the curtain; serving as a battery to defend the face of the opposite bastion, and the moat or ditch.

It is now seldom used, because the batteries of the enemy are apt to bury the artillery of the casemate in the ruins of the vault; beside, the great smoke made by the discharge of the cannon renders it intolerable to the men. So that, instead of the ancient covered casemates, later engineers have contrived open ones, only guarded by a parapet, &c.

CASEMATE is also used for a well with several subterraneous branches, dug in the passage of the bastion, till the miner is heard at work, and air given to the mine.

CASSINI (James), a celebrated French astronomer, was born at Paris February 18. 1677, being the younger son of Johannes Dominicus Cassini, of whom some account has been given in the *Encyclopadia*.

C A S

After his first studies in his father's house, in which it is not to be supposed that mathematics and astronomy would be neglected, he was sent to study philosophy at the Mazarine college, where the celebrated Varignon was then professor of mathematics. From the assistance of this eminent young man Cassini profited so well, that at 15 years of age he supported a mathematical thesis with great honour. At the age of 17 he was admitted a member of the Academy of Sciences; and the same year he accompanied his father in a journey to Italy, where he assisted him in the verification of the meridian at Bologna and other measurements. On his return he performed similar operations in a journey into Holland, where he discovered some errors in the measure of the earth by Snell, the result of which was communicated to the Academy in 1702. He made also a visit to England in 1696, where he was made a member of the Royal Society. In 1712 he succeeded his father as astronomer royal at the observatory of Paris. In 1717 he gave to the Academy his researches on the distance of the fixed stars; in which he shewed that the whole annual orbit, of near 200 millions of miles diameter, is but as a point in comparison of that distance. The same year he communicated,

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municated also his discoveries concerning the inclination of the orbits of the satellites in general, and especially of those of Saturn's satellites and ring. In 1725 he undertook to determine the cause of the moon's libration, by which she shews sometimes a little towards one side, and sometimes a little on the other, of that half which is commonly behind or hid from our view.

In 1732 an important question in astronomy exercised the ingenuity of our author. His father had determined, by his observations, that the planet Venus revolved about her axis in the space of 23 hours; and M. Bianchini had published a work in 1729, in which he settled the period of the same revolution at 24 days 8 hours. From an examination of Bianchini's observations which were upon the spots in Venus, he discovered that he had intermitted his observations for the space of three hours, from which cause he had probably mistaken new spots for the old ones, and so had been led into the mistake. The probability is, that both had fallen into some mistake, or that they had proceeded on very different principles; for otherwise such different results are wholly unaccountable. Dr Herschel seems satisfied that the period of the revolution is less than Bianchini has made; but he does not say what it is, or that it is not much greater than it was supposed by Cassini. Our author, after he had convicted Bianchini, as he thought, of error, determined the nature and quantity of the acceleration of the motion of Jupiter at half a second per year, and of that of the retardation of Saturn at two minutes per year; that these quantities would go on increasing for 2000 years, and then would decrease again. In 1740 he published his *Astronomical Tables*, and his *Elements of Astronomy*; very extensive and accurate works.

Although astronomy was the principal object of our author's consideration, he did not confine himself absolutely to that branch, but made occasional excursions into other fields. We owe also to him, for example, *Experiments on Electricity*, or the *Light produced by Bodies by Friction*; *Experiments on the Recoil of Firearms*; *Researches on the Rise of the Mercury in the Barometer at different Heights above the Level of the Sea*; *Reflections on the perfecting of Burning-glasses*; and other *Memoirs*.

The French Academy had properly judged, that one of its most important objects was the measurement of the earth. In 1669 Picard measured a little more than a degree of latitude to the north of Paris; but as that extent appeared too small from which to conclude the whole circumference with sufficient accuracy, it was resolved to continue that measurement on the meridian of Paris to the north and the south, through the whole extent of the country. Accordingly, in 1683, the late M. de la Hire continued that on the north side of Paris, and the older Cassini that on the south side. The latter was assisted in 1700 in the continuation of this operation by his son our author. The same work was farther continued by the same academicians; and, finally, the part left unfinished by De la Hire in the north was finished in 1718 by our author, with the late Maraldi, and De la Hire the younger.

These operations produced a considerable degree of precision. It appeared also, from this measured extent of six degrees, that the degrees were of different lengths in different parts of the meridian; and in such sort that

our author concluded, in the volume published for 1718, that they decreased more and more towards the pole, and that therefore the figure of the earth was that of an oblong spheroid, or having its axis longer than the equatorial diameter. He also measured the perpendicular to the same meridian, and compared the measured distance with the differences of longitude as before determined by the eclipses of Jupiter's satellites: whence he concluded that the length of the degrees of longitude was smaller than it would be on a sphere, and that therefore again the figure of the earth was an oblong spheroid, contrary to the determination of Newton by the theory of gravity. Though Newton was of all men the most averse from controversy, the other mathematicians in Britain did not tamely submit to conclusions in direct opposition to the fundamental doctrine of a philosopher of whose talents the nation was justly proud. The consequence was, that the French government sent two different sets of measurers, the one to measure a degree at the equator, the other at the polar circle; and the comparison of the whole determined the figure to be an oblate spheroid, contrary to Cassini's determination.

After a long and laborious life, James Cassini died in April 1756, in consequence of a fall, and was succeeded in the Academy and Observatory by the subject of the following article. He published, *A Treatise on the Magnitude and Figure of the Earth*; as also, *The Elements or Theory of the Planets*, with *Tables*; beside an infinite number of papers in the *Memoirs of the Academy*, from the year 1699 to 1755.

CASSINI de Thury (Cesar François), a celebrated French astronomer, director of the observatory, pensioner astronomer, and member of most of the learned societies of Europe, was born at Paris June 17. 1714, being the second son of James Cassini, the subject of the preceding memoir, whose occupations and talents he inherited and supported with great honour. He received his first lessons in astronomy and mathematics from MM. Maraldi and Camus; and made such a rapid progress, that when he was not more than ten years of age he calculated the phases of a total eclipse of the sun. At the age of eighteen he accompanied his father in his two journeys undertaken for drawing the perpendicular to the observatory meridian from Strasbourg to Brest. From that time a general chart of France was devised; for which purpose it was necessary to traverse the country by several lines parallel and perpendicular to the meridian of Paris, and our author was charged with the conduct of this business; in which he was so scrupulous as to measure again what had been measured by his father. This great work was published in 1740, with a chart shewing the new meridian of Paris, by two different series of triangles, passing along the sea coasts to Bayonne, traversing the frontiers of Spain to the Mediterranean and Antibes, and thence along the eastern limits of France to Dunkirk, with parallel and perpendicular lines described at the distance of 6000 toises from one another, from side to side of the country.

A tour which, in 1741, our author made in Flanders, in the train of the king, gave rise, at his majesty's instance, to the chart of France; relative to which Cassini published different works, as well as a great number of the sheets of the chart itself. In 1761 he undertook an expedition into Germany, for the purpose of continuing to Vienna the perpendicular of the Pa-

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ris meridian; to unite the triangles of the chart of France with the points taken in Germany; to prepare the means of extending into that country the same plan as in France; and thus to establish successively for all Europe a most useful uniformity.— Our author was at Vienna the 6th of June 1761, the day of the transit of the planet Venus over the sun, of which he observed as much as the state of the weather would permit him to do, and published the account of it in his *Voyage en Allemagne*.

Finally, M. Cassini, always meditating the perfection of his grand design, profited of the peace of 1763 to propose the joining of certain points taken upon the English coast with those which had been determined on the coast of France, and thus to connect the general chart of the latter with that of the British isles, like as he had before united it with those of Flanders and Germany. The proposal was favourably received by the English government, and presently carried into effect under the direction of the Royal Society, the execution being committed to the late General Roy. See the life of that general in this *Supplement*.

Between the years 1735 and 1770, M. Cassini published, in the volumes of *Memoirs of the French Academy*, a prodigious number of pieces, consisting chiefly of astronomical observations and questions; among which are observable, researches concerning the parallax of the sun, the moon, Mars; and Venus; on astronomical refractions, and the effect caused in their quantity and laws by the weather; numerous observations on the obliquity of the ecliptic, and on the law of its variations. In short, he cultivated astronomy for fifty years, the most important for that science that ever elapsed for the magnitude and variety of objects, in which he commonly sustained a principal share.

M. Cassini was of a very strong and vigorous constitution, which carried him through the many laborious operations in geography and astronomy which he conducted. An habitual retention of urine, however, rendered the last twelve years of his life very painful and distressing, till it was at length terminated by the small-pox the 4th of September 1784, in the 71st year of his age. He was succeeded in the academy, and as director of the observatory, by his only son John-Dominic Cassini, the fourth in order of direct descent who has filled that honourable station.

CASTRAMETATION, the art or act of encamping an army.

CATACAUSTICS, or CATACAUSTIC CURVES, in the higher geometry, are the species of caustic curves formed by reflection.

CATACOUSTICS, or CATAPHONICS, is the science of reflected sounds; or that part of acoustics which treats of the properties of echoes.

CATALOGUES OF BOOKS, is a subject of which a very curious history has been given to the world by Professor Beckmann. In the *Encyclopædia* mention has been made of some of the most valuable catalogues, their defects pointed out, and rules given for making them

more perfect; but nothing has there been said of their origin, or of the uses which might be made of the oldest catalogues.

According to the Professor, George Willer, whom some improperly call Viller, and others Walter, a book-feller at Augsburg, who kept a very large shop, and frequented the Franckfort fairs, first fell upon the plan of causing to be printed, before every fair, a catalogue of all the new books, in which the size and printers names were marked. Le Mire, better known under the name of Miræus, says that catalogues were first printed in the year 1554; but Labbe (A), Reimann (B), and Heumann (C), who took their information from Le Mire, make the year erroneously to be 1564. Willer's catalogues were printed till the year 1592 by Nicol. Bassæus, printer at Franckfort. Other bookfellers, however, must have soon published catalogues of the like kind, though that of Willer continued a long time to be the principal.

In all these catalogues, which are in quarto and not paged, the following order is observed. The Latin books occupy the first place, beginning with the Protestant theological works, perhaps because Willer was a Lutheran; then come the Catholic; and after these, books of jurisprudence, medicine, philosophy, poetry, and music. The second place is assigned to German books, which are arranged in the same manner.

The bookfellers of Leipzig soon perceived the advantage of catalogues, and began not only to reprint those of Franckfort, but also to enlarge them with many books which had not been brought to the fairs in that city. Our author had for some time in his custody, *Catalogus universalis pro nundinis Francofurtensibus vernalibus, de anno 1600*; or, A catalogue of all the books on sale in Book-street, Franckfort, and also of the books published at Leipzig, which have not been brought to Franckfort, with the permission of his highness the elector of Saxony, to those new works which have appeared at Leipzig. Printed at Leipzig by Abraham Lamberg, and to be had at his shop. On the September catalogue of the same year, it is said that it is printed from the Franckfort copy with additions. He found an Imperial privilege for the first time on the Franckfort September catalogue of 1616: *Cum gratia et privilegio speciali s. caes. maj. Prostat apud J. Krugerum Augustanum*.

Reimann says, that after Willer's death the catalogue was published by the Leipzig bookfeller Henning Grosse, and by his son and grandson. The council of Franckfort caused several regulations to be issued respecting catalogues; an account of which may be seen in D. Orth's *Treatise on the Imperial Fairs at Franckfort*. After the business of bookfelling was drawn from Franckfort to Leipzig, occasioned principally by the restrictions to which it was subjected at the former by the censors, no more catalogues were printed there; and the shops in Book-street were gradually converted into taverns (D).

“ In the 16th century there were few libraries; and these, which did not contain many books, were in monasteries,

- (A) Labbe, *Bibliotheca Bibliothecarum*. Lipsiæ, 1682, 12mo, p. 112.
 (B) *Einleitung in die Historiam Literariam*, i. p. 203.
 (C) *Conspectus Reip. Litter. c. vi. § 2. p. 316.*
 (D) Joh. Adolph. Stock, *Frankfurter Chronik*, p. 77.

naeries, and consisted principally of theological, philosophical, and historical works, with a few, however, on jurisprudence and medicine; while those which treated of agriculture, manufactures, and trade, were thought unworthy of the notice of the learned, or of being preserved in large collections. The number of these works was, nevertheless, far from being inconsiderable; and at any rate, many of them would have been of great use, as they would have served to illustrate the instructive history of the arts. Catalogues which might have given occasion to inquiries after books, that may be still somewhere preserved, have suffered the fate of tomb-stones, which, being wasted and crumbled to pieces by the destroying hand of time, become no longer legible. A complete series of them perhaps is nowhere to be found, at least I do not remember (says the Professor) to have ever seen one in any library."

This loss, however, he thinks, might be in some measure supplied by the catalogues of Cless and Draudius; who, by the desire of some booksellers, collected together all the catalogues which had been published at the different fairs in different years. The work of Cless has the following title: *Unius seculi ejusque virorum litterarum monumentis tum florentissimi, tum fertilissimi, ab anno 1500 ad 1602 nundinarum autumnalium inclusive, elenchus consummatissimus—desumptus partim ex singularum nundinarum catalogis, partim ex bibliothecis.* Auctore Joanne Clessio, Wineccensi, Hannoio, philosopho ac medico.—By the editor's preface, it appears that the first edition was published in 1592. The order is almost the same as that observed by Willer in his catalogues.

The work of Draudius, which was printed in several quarto volumes for the first time in 1611, and afterwards in 1625, is far larger, more complete, and more methodical. Our author, however, confesses, that he never saw a perfect copy of either edition. This catalogue consists of three parts; of which the first has the title of *Bibliotheca classica, sive Catalogus officinalis, in quo singuli singularum facultatum ac professionum libri, qui in quavis fere lingua extant—recensentur; usque ad annum 1624 inclusive.* Auctore M. Georgio Draudio.—It contains Latin works on theology, jurisprudence, medicine, history, geography, and politics. The copy in the library of the university of Gottingen ends at page 1304, which has, however, a catch-word, that seems to indicate a deficiency.—The second part is intitled, *Bibliotheca classica sive Catalogus officinalis, in quo philosophici artiumque adeo humaniorum, poetici etiam et musici libri usque ad annum 1624 continentur.* This part, containing Latin books also, begins at page 1298, and ends with page 1654, which is followed by an index of all the authors mentioned.—A smaller volume, of 302 pages, without an index, has for title, *Bibliotheca exotica, sive Catalogus officinalis librorum peregrinis linguis usualibus scriptorum.* And a third part, forming 759 pages, besides an index of the authors, is called, *Bibliotheca librorum Germanicorum classica*; that is, A catalogue of all the books printed in the German language till the year 1625.

We have reason to believe that there are other editions of this catalogue than those mentioned by Professor Beckmann; and it might become some prince or great man, for it is not a work for a bookseller, to compare all the editions together, and publish a new one more correct than any that is at present extant. This

indeed would be an expensive and not an easy task; for our author observes, that all the oldest catalogues had the same faults as those of later date, and that these faults have been copied by Draudius. Many books are mentioned which were never printed, and many titles, names, and dates, are given incorrecly; but Draudius nevertheless is well worth the attention of any one who may be inclined to employ his time and ingenuity on the history of literature; and his work certainly was of use to Haller when he composed his *Bibliotheca*.

CATALOGUES of the Stars, have usually been disposed, either as collected into certain figures called *constellations*, or according to their right ascensions, that is, the order of their passing over the meridian.

Of the principal catalogues, according to the first of these forms, an account has been given in the *Encyclopaedia*. The first catalogue, we believe, that was printed in the new or second form, according to the order of the right ascensions, is that of De la Caille, given in his *Ephemerides* for the ten years between 1755 and 1765, and printed in 1755. It contains the right ascensions and declinations of 307 stars, adapted to the beginning of the year 1750. In 1757 De la Caille published his *Astronomie Fundamenta*, containing a catalogue of the right ascensions and declinations of 398 stars, likewise adapted to the beginning of 1750. And in 1763, the year after his death, was published the *Calum Australe Stelliferum* of the same author; containing a catalogue of the places of 1942 stars, all situated to the southward of the tropic of Capricorn, and observed by him while he was at the Cape of Good Hope in 1751 and 1752; their places being also adapted to the beginning of 1750. In the same year was published his *Ephemerides* for the ten years between 1765 and 1775; in the introduction to which are given the places of 515 zodiacal stars, all deduced from the observations of the same author; the places adapted to the beginning of the year 1765.

In the Nautical Almanac for 1773, is given a catalogue of 387 stars, in right ascension, declination, longitude, and latitude, derived from the observations of the late celebrated Dr Bradley, and adjusted to the beginning of the year 1760. This small catalogue, and the results of about 1200 observations of the moon, are all that the public have yet seen of the multiplied labours of this most accurate and indefatigable observer, although he has now (1798) been dead upwards of 38 years.

In 1775 was published a thin volume, intitled *Opera Inedita*, containing several papers of the late Tobias Mayer, and among them a catalogue of the right ascensions and declinations of 998 stars, which may be occulted by the moon and planets; the places being adapted to the beginning of the year 1756.

At the end of the first volume of "Astronomical Observations made at the Royal Observatory at Greenwich," published in 1776, Dr Maskelyne, the present astronomer royal, has given a catalogue of the places of 34 principal stars, in right ascension and north polar distance, adapted to the beginning of the year 1770.

These being the result of several years repeated observations, made with the utmost care and the best instruments, it may be presumed are exceedingly accurate.

In 1782, M. Bode of Berlin published a very extensive catalogue of 5058 of the fixed stars, collected from

Catalogues of the Stars. from the observations of Flamsteed, Bradley, Hevelius, Mayer, De la Caille, Messier, Monnier, D'Arqueir, and other astronomers; all adapted to the beginning of the year 1780; and accompanied with a celestial atlas or set of maps of the constellations, engraved in a most delicate and beautiful manner.

To these may be added Dr Herschel's catalogue of double stars, printed in the Phil. Transf. for 1782 and 1783; Messier's nebulae and clusters of stars, published in the *Connoissance des Temps* for 1784; and Herschel's catalogue of the same kind, given in the Phil. Transf. for 1786.

In 1789 Mr Francis Wollaston published "A Specimen of a General Astronomical Catalogue, in Zones of North-polar Distance, and adapted to January 1. 1790." These stars are collected from all the catalogues before-mentioned, from that of Hevelius downwards. This work contains five distinct catalogues; viz. Dr Maskelyne's new catalogue of 36 principal stars; a general catalogue of all the stars, in zones of north-polar distance; an index to the general catalogue; a catalogue of all the stars, in the order in which they pass the meridian; and a catalogue of zodiacal stars, in longitude and latitude.

Finally, in 1792, Dr Zach published at Gotha, *Tabula Motuum Solis*; to which is annexed a new catalogue of the principal fixed stars, from his own observations made in the years 1787, 1788, 1789, 1790. This catalogue contains the right ascensions and declinations of 381 principal stars, adapted to the beginning of the year 1800.—*Hutton's Mathematical Dictionary*.

Besides these two methods of forming catalogues of the stars, Dr Herschel has conceived a new one, in which the comparative brightness of the stars is accurately expressed. It is long since astronomers were first led to arrange the stars in classes of different magnitudes by their various degrees of brilliancy or lustre. Brightness and size have at all times been considered as synonymous terms; so that the brightest stars have been referred to the class comprehending those of the first magnitude; and as the subsequent orders of stars have been supposed to decrease in lustre, their magnitude has been determined in the same decreasing progression: but the want of some fixed and satisfactory standard of lustre has been the source of considerable confusion and uncertainty in settling the relative magnitudes of the stars. A star marked 1. 2m. is supposed to be between the first and second magnitude; but 2. 1m. intimates that the star is nearly of the second magnitude, and that it partakes somewhat of the lustre of a star of the first order. Such subdivisions may be of some use in ascertaining stars of the first, second, and third classes; but the expressions 5m, 5.6m, 6.5m, 6m, must be very vague and indefinite. Dr Herschel observes that he has found them so in fact; and he therefore considers this method of pointing out the different lustre of stars as a reference to an imaginary standard. If any dependence could be placed on this method of magnitudes, "it would follow, that no less than eleven stars in the constellation of the Lion, namely, β σ π ξ A b c d 54, 48, 72, had all undergone a change in their lustre since Flamsteed's time: For if the idea of magnitudes had been a clear one, our author, who marked β 1.2m. and γ 2m. ought to be understood to mean that β is larger than γ ; but we now find that actually γ is larger than β . Every one of the

eleven stars (says Dr Herschel) which I have pointed out may be reduced to the same contradiction." Catalogues of the Stars.

The author has pointed out the instances of the insufficiency of this method, and of the uncertain conclusions that are deduced from it, in determining the comparative brightness of stars found not only in Mr Flamsteed's catalogue, but also in the catalogues of other astronomers. It is sufficiently apparent that the present method of expressing the brightness of the stars is very defective. Dr Herschel therefore proposes a different mode, that is more precise and satisfactory.

"I place each star (he says), instead of giving its magnitude, into a short series, constructed upon the order of brightness of the nearest proper stars. For instance, to express the lustre of D, I say CDE. By this short notation, instead of referring the star D to an imaginary uncertain standard, I refer it to a precise and determined existing one. C is a star that has a greater lustre than D, and E is another of less brightness than D. Both C and E are neighbouring stars, chosen in such a manner that I may see them at the same time with D, and therefore may be able to compare them properly. The lustre of C is in the same manner ascertained by BCD; that of B by ABC; and also the brightness of E by DEF; and that of F by EFG.

"That this is the most natural, as well as the most effectual way to express the brightness of a star, and by that means to detect any change that may happen in its lustre, will appear, when we consider what is requisite to ascertain such a change. We can certainly not wish for a more decisive evidence, than to be assured, by actual inspection, that a certain star is now no longer more or less bright than such other stars to which it has been formerly compared; provided we are at the same time assured that those other stars remain still in their former unaltered lustre. But if the star D will no longer stand in its former order CDE, it must have undergone a change; and if that order is now to be expressed by CED, the star has lost some part of its lustre; if, on the contrary, it ought now to be denoted by DCE, its brightness must have had some addition. Then, if we should doubt the stability of C and E, we have recourse to the orders BCD and DEF, which express their lustre; or even to ABC and EFG, which continue the series both ways. Now having before us the series BCDEF, or if necessary even the more extended one ABCDEFG, it will be impossible to mistake a change of brightness in D, when every member of the series is found in its proper order except D."

In the author's journal or catalogue, in which the order of the lustre of the stars is fixed, each star bears its own proper name or number, e. g. "the brightness of the star δ Leonis may be expressed by $\beta \delta \epsilon$ Leonis, or better by 94—68—17 Leonis; these being the numbers which the three above stars bear in the British catalogue of fixed stars."

This method of arrangement occurred to Dr Herschel so early as the year 1782; but he was diverted from the regular pursuit of it by a variety of other astronomical engagements. After many trials, he proposed, in the Transactions of the Royal Society of London for 1796, the plan which appeared to him the most eligible. It is as follows:—Instead of denoting particular stars by letters, he makes use of numbers; and in his choice of the stars which are to express the lustre

of any particular one, he directs his first view to perfect equality.* When two stars seem to be similar both in brightness and magnitude, he puts down their numbers together, separated merely by a point, as 30.24 Leonis; but if two stars, which at first seemed alike in their lustre, appeared on a longer inspection to be different, and the preference should be always decidedly in favour of the same star, he separates these stars by a comma, thus, 41,94 Leonis. This order must not be varied; nor can three such stars, as 20, 40, 39, Libræ, admit of a different arrangement. If the state of the heavens should be such as to require a different order in these numbers, we may certainly infer that a change has taken place in the lustre of one or more of them. When two stars differ very little in brightness, but so that the preference of the one to the other is indisputable, the numbers that express them are separated by a short line, as 17—70 Leonis, or 68—17—70 Leonis. When two stars differ so much in brightness, that one or two other stars might be interposed between them, and still leave sufficient room for distinction, they are distinguished by a line and comma, thus, —, or by two lines, as 32— —41 Leonis. A greater difference than this is denoted by a broken line, thus — — —29 Bootis. On the whole, the author observes, the marks and distinctions which he has adopted cannot possibly be mistaken; “a point denoting equality of lustre; a comma indicating the least perceptible difference; a short line to mark a decided but small superiority; a line and comma, or double line, to express a considerable and striking excess of brightness; and a broken line to mark any other superiority which is to be looked upon as of no use in estimations that are intended for the purpose of directing changes.”

The difficulties that attend this arrangement are not disguised; but the importance and utility of it more than compensate for the labour which it must necessarily require. By a method of this kind, many discoveries of changeable and periodical stars might probably have been made, which have escaped the most diligent and accurate observers. We might then, as the author suggests, be enabled to resolve a problem in which we are all immediately concerned.

“Who, for instance, would not wish to know what degree of permanency we ought to ascribe to the lustre of our sun? Not only the stability of our climates, but the very existence of the whole animal and vegetable creation itself, is involved in the question. Where can we hope to receive information upon this subject but from astronomical observations? If it be allowed to admit the similarity of stars with our sun as a point established, how necessary will it be to take notice of the fate of our neighbouring *sun*, in order to guess at that of our own? That *star*, which among the multitude we have dignified by the name of *sun*, to-morrow may slowly begin to undergo a gradual decay of brightness, like β Leonis, α Ceti, α Draconis, δ Ursa majoris, and many other diminishing stars that will be mentioned in my catalogues. It may suddenly increase, like the wonderful star in the back of Cassiopea’s chair, and the no less remarkable one in the foot of Serpentarius; or gradually come on like β Geminorum, β Ceti, ζ Sagittarii, and many other increasing stars, for which I also refer to my catalogues; and, lastly, it may turn into a periodical one of 25 days duration, as Algol is one of three days,

δ Cephei of five, β Lyrae of six, η Antinoi of seven days, and as many others as are of various periods.”

Having thus explained the general principle on which this catalogue is formed, as we find it in the author’s first memoir on the subject, we must refer the reader to the Doctor’s own account for its particular arrangement; observing only that the catalogue subjoined comprehends nine constellations, which are arranged in alphabetical order, with the comparative brightness of the stars accurately stated. In a subsequent paper, published in the same volume, he has completely verified the utility of his method by experience, and shewn that there is no permanent change of lustre in the stars. In the notes to his first catalogue he mentioned α Herculis as a periodical star. By a series of observations on this star, compared with \times Ophiuchi, which was most conveniently situated for his purpose, he has been able not only to confirm this opinion, but to ascertain its period. His observations are arranged in a table, by means of which he determines that this star had gone through four successive changes in an interval of 241 days; and therefore the duration of its period must be about 60 days and a quarter. This fact concurs with other circumstances in evincing the rotatory motion of the stars on their axes. “Dark spots, or large portions of the surface, less luminous than the rest, turned alternately in certain directions, either towards or from us, will account for all the phenomena of periodical changes in the lustre of the stars, so satisfactorily, that we certainly need not look out for any other cause.” If it be alleged that the periods in the change of lustre of some stars, such as Algol, β Lyrae, δ Cephei, and η Antinoi, are short, being only 3, 5, 6, and 7 days respectively; while those of σ Ceti, and of the changeable star in Hydra, and that in the neck of the Swan, are long, amounting to 331, 394, and 497 days; and that we cannot ascribe phenomena so different in their duration to the same cause—it may be answered to this objection, that the force of it is founded on our limited acquaintance with the state of the heavens. To the 7 stars, the periodical changes of which were before known, we may now add α Herculis, which performs a revolution of its changes in 60 days.

“The step from the rotation of α Herculis to that of σ Ceti is far less considerable than that from the period of Algol to the rotation of α Herculis; and thus a link in the chain is now supplied, which removes the objection that arose from the vacancy.” The rotation of the fifth satellite of Saturn is proved by the change observable in its light; and “this variation of light, owing to the alternate exposition of a more or less bright hemisphere of this periodical satellite, plainly indicates that the similar phenomenon of a changeable star arises from the various lustre of the different parts of its surface, successively turned to us by its rotatory motion.”

Besides, we perceive a greater similarity between the sun and the stars, by means of the spots that must be admitted to exist on their surfaces, as well as on that of the sun.

Dr Herschel farther observes, that the stars, besides a rotatory motion on their axes, may have other movements; “such as nutations or changes in the inclination of their axes; which, added to bodies much flattened by quick rotatory motions, or surrounded by rings like Saturn, will easily account for many new phenomena

Catenaria, na that may then offer themselves to our extended views." Catharine. To this paper is likewise subjoined a catalogue of nine constellations; and the author promises to give the whole of them in successive short catalogues on the same plan.

CATENARIA, or CATENARY CURVE. See *Encycl.* and ARCH in this *Supplement*.

CATHARINE II. Empress of all the Russias, acted so conspicuous a part on the theatre of the world; possessed such uncommon powers of mind, highly cultivated by science and literature; and was such a patroness of science and literature in others—that it cannot be deemed foreign from a work of this nature to give some account of the principal events of her more private life.

SOPHIA AUGUSTA FREDERICA, who, upon her marriage to the grandson of Peter the great, assumed the name CATHARINA ALEXIEVNA, was born at *Stettin* on the 2d of May 1729. Her father was Christian Augustus, prince of Anhalt Zerbst Dornburg, at that time major-general in the Prussian service, commander in chief of the regiments of infantry, and governor of the town and fortrefs of *Stettin*. Her mother, who was born princess of Holstein Eutin, was a woman of great parts and beauty, of nearly the same age with the prince-royal of Prussia, afterwards Frederic the Great, with whom she kept up a regular correspondence, and who afterwards contributed to the aggrandisement of her daughter. This accomplished princess took upon herself the care of educating the young Sophia, whom she brought up in the simplest manner, and would not suffer to exhibit the least symptoms of that pride to which she had some propensity from her earliest childhood. The consequence of this salutary restraint was, that good humour, intelligence, and spirit, were even then the striking features of her youthful character. Being naturally addicted to reading, to reflection, to learning, and to employment, she was taught the French and other fashionable languages; and was instructed to read such books chiefly as might make her acquainted with history and with the principles of science; whilst the doctrines of the Lutheran religion were carefully explained to her by a divine, who little thought how soon his illustrious pupil would embrace another faith.

The Empress Elizabeth, who then swayed the sceptre of Russia, had in early life been promised in marriage to the young prince of Holstein Eutin, brother to the princess of Anhalt Zerbst; but at the instant when the marriage was about to be celebrated, the prince fell sick and died. Elizabeth, who loved him to excess, became inconsolable, and in the bitterness of her grief made a vow of celibacy. This vow, though sensual, and even lascivious, she kept so far as never publicly to acknowledge any man as a husband; and upon her ascending the throne of her ancestors, she called her nephew the Duke of Holstein Gottorp to her court, where he was solemnly proclaimed, when fourteen years of age, Grand Duke, with the title of Imperial Highness, and declared successor to the Empress Elizabeth. To secure the succession in the family of Peter the Great, the Empress was very desirous to have her nephew married; and the princess of Anhalt Zerbst, not ignorant of the tender remembrance which she still preserved for her brother, conceived the idea of placing, by means of it, her daughter on the throne of Russia. She communicated her

plan to the king of Prussia, who not only applauded it, but lent her his assistance to carry it into execution.

Full of ambitious hopes, therefore, the princess repaired with her daughter to St Petersburg, where she was received with friendship by Elizabeth, and where the young Sophia soon made a considerable impression on the mind of the Grand Duke. As Peter was well made, of a good figure, and, though uneducated, not destitute of natural talents, the attachment became reciprocal; and the princess of Zerbst, throwing herself at the feet of the empress, assured her, that the two lovers were attached to each other by a passion unconquerable; and, calling to her mind the love which she had herself borne to the prince of Holstein, conjured her to promote the happiness of that prince's niece. The stratagem succeeded. The choice of Elizabeth was next day announced to the council and to the foreign ministers; and preparations were made for celebrating the marriage with a magnificence worthy of the heir of the throne of the Russias. In the mean time the Grand Duke was seized with the small-pox, from which, tho' he recovered, it was with such a change of features, as rendered him, from being comely, almost hideous, and converted the love of the young princess of Anhalt, if indeed she ever felt for him that passion, into horror and disgust. She was not, however, of a disposition to let a disfigured countenance frighten her from a throne. She embraced the Greek religion, changed her name from Sophia Augusta Frederica to CATHARINA ALEXIEVNA, and with the entire approbation of Elizabeth was married to her nephew the Grand Duke.

For some time this ill-matched pair lived together, though without love, yet on terms apparently decent; but a mutual dislike gradually took place between them, which the courtiers quickly discovered, and were at pains to foment into hatred. Peter was now ugly, and his mind was uninformed. Catharine, if not a beauty, was at least a lovely woman, and highly accomplished. She could find no entertainment in his conversation, and he felt himself degraded by her superiority. A faction was formed at court, headed by the great chancellor Bestucheff, to exclude the Grand Duke from the throne, and to place Catharine at the head of affairs; and to accomplish this end, every art was employed to fill the feeble mind of the empress with jealousies of her nephew, and with a contempt of his character. He was represented at one time as extremely ambitious, and capable of the most daring enterprises, to get immediate possession of the throne; and at another, as a wretch given up to drunkenness and to every unprincipled vice.

The consequence of the first of these accusations was, that he was kept at a distance from his aunt, and a stranger to public affairs; and being wholly unemployed, that time which his education had not fitted him to fill up with reading, reflection, and rational conversation, hung so heavy on his mind, that it was no difficult matter for those dissipated young men, who were placed about him for that very purpose, to initiate him in the habits of drunkenness, and the other mean practices to which it was pretended he had long been devoted. In such a school, it was no wonder that he became a proficient in grovelling dissipation; or that, being unpolished, and even of rude manners, he chose for his companions some of the lowest of the people.

Catharine, in the mean time, languished for that happiness

Catharine. pinefs which ſhe could not find in the ſociety of her husband. She was fond of pleaſure; but it was that comparatively refined pleaſure which ſhe had enjoyed at the court of Berlin. She loved balls, muſic, and elegant converſation, and could take no ſhare in the drunken revels of Peter. Among the young men with whom he was ſurrounded, his chamberlain Soltikoff was particularly remarked for the elegance of his taſte and the graces of his perſon; and though yet ſcarcely more than a boy in years, he was ſaid to have obtained the favours of ſeveral ladies of the court. Succeſs had made him confident and ambitious; and his ambition prompted him to aſpire at making a conqueſt even of the Grand Duchefs. By ſtudying her taſte, and contriving to amuſe her, he was at laſt ſucceſsful; and obtained from her Imperial Highneſs every favour which he could wiſh: but he enjoyed not his fortune with moderation, and his enemies contrived to get him placed in an honourable office at a diſtance from the court. He was com-miſſioned to repair to Stockholm, with the title of Envoy Extraordinary, to notify to the king of Sweden the birth of Paul Petrovitch, of whom the Grand Duchefs had juſt been delivered*. The preſumptuous Soltikoff, proud of the employment, ſet off with haſte to Sweden, and left it with equal ſpeed. But ſcarcely had he quitted Stockholm, on the wings of love and ambition, when he was ſtopped on the road by a courier, who put into his hands an order for him to go immediately to Hamburg, and there to reſide in the quality of miniſter plenipotentiary from the court of Ruſſia.

* Oct. 1.
1754.

Catharine for ſome time preſerved her attachment to the exiled chamberlain; but all at once the preſence of a ſtranger, whom fortune had brought to the court of Ruſſia, made her forget the lover whom ſhe no longer ſaw. This perſon was Stanislaus Poniatowſky, the late king of Poland, who firſt made his appearance at St Peterſburg in the train of the Britiſh ambaffador, and very quickly gained the affections of the Grand Duchefs. In carrying on this intrigue, the lovers were not ſo cautious as to deceive the eyes of the envious courtiers, who reported to the empreſs not only all that they ſaw, but whatever they ſuſpected. Elizabeth was incenſed, and commanded Poniatowſky to quit without delay the dominions of Ruſſia. The accomplished Pole obeyed; but ſoon returned clothed with a character which made him in ſome degree independent of the empreſs.

The Count de Bruhl, then prime miniſter to the king of Poland, ſaw of what importance it was to his maſter to have a powerful intereſt at the court of Ruſſia. He was likewise no ſtranger to the paſſion which the Grand Duchefs entertained for Poniatowſky; and having got that nobleman decorated with the order of the White Eagle, he ſent him back to St Peterſburgh in the quality of miniſter plenipotentiary from the republic and king of Poland. Nor was this all that Bruhl did for the two lovers. Being informed by the chancellor Beſtucheff, that the Grand Duke and Grand Duchefs were languiſhing in a penury unworthy of their rank, he remitted to Poniatowſky 6000 ducats, to be employed, in ſuch a manner as he might judge beſt, for ſecuring the favour of the prince and his conſort. The ambaffador profited by theſe counſels and benefactions. He was already ſure of the Grand Duchefs's heart, and he very quickly gained the favour of her husband. He talked Engliſh and German with him; drank, ſmoked,

abused the French, and extolled the king of Pruffia with unlimited praife. Catharine.

The Grand Duchefs was ſo blinded by her paſſion, that ſhe was never without Poniatowſky in her company. She devoted to him the whole of her time; and ſhe made this intimacy ſo little a ſecret, that public report was loud to her prejudice. In the mean time ſhe was delivered of the Princeſs Anne†, who lived only fifteen † February 1758. months. The Grand Duke was the only perſon about court who ſeemed to know nothing of what was paſſing. His whole time was occupied in copying, with fervile affectation, the air, the manners, the tone of the king of Pruffia; and in dreſſing a little army at Oranianbaum in the Pruffian uniform. His eyes, however, were at laſt opened. Some of the courtiers, from hatred to the chancellor, who countenanced the intrigue between the Grand Duchefs and the Polish ambaffador, rouſed his jealousy in order to deſtroy their enemy. They ſucceeded. He forbade his wife to be ſeen with Poniatowſky, and prevailed with the empreſs to deprive the chancellor of his office, and to baniſh him to an eſtate which he had 120 verſts beyond Moſcow.

Catharine had now to ſupport at once the averſion of her husband, the indignation of the empreſs, the inſulting diſdain of a court, which a few days before was laſh of its affiduities and ſmiles; and what afflicted her moſt of all, the dread of loſing for ever her favourite Poniatowſky. Her courage, however, did not forſake her. Poniatowſky was indeed recalled, and left Ruſſia, after ſuffering ſome deſerved indignities from the Grand Duke, who about this time formed a connection with one of the daughters of the Senator Vorontzoff, brother to the new chancellor. This lady, Elizabeth Romanovna Vorontzoff, was elder ſiſter to the Princeſs Daſh-koff, who acted ſo conspicuous a part in the revolution which ſet the crown on the head of Catharine. She was beautiful, but vain; and poſſeſſed not either the wit or the underſtanding of her ſiſter.

In the mean time the health of the empreſs viſibly declining, Catharine was very deſirous of being reconciled to her: but the irritated ſovereign would liſten to no accommodation, except on terms too humiliating for the haughty ſpirit of the Grand Duchefs. Catharine, therefore, abſented herſelf from court, and asked permiſſion to retire into Germany. This, as ſhe had foreſeen, was reſuſed. Elizabeth was too fond of the young Paul Petrovitch to permit the departure of his mother, and thereby expoſe him to the danger of being at ſome future period declared illegitimate. She took the Grand Duchefs again into favour; and it is thought, that had ſhe lived a little longer than ſhe did, ſhe would have excluded Peter from the throne, and declared Paul her immediate ſucceſſor.

While the empreſs was meditating the aggrandiſement of the young prince and his mother, the Grand Duke had conceived a plan for degrading them both. He had reſolved, at the moment his aunt ſhould cloſe her eyes, to aſſemble his troops, to get himſelf proclaimed emperor, to repudiate the Grand Duchefs, to declare the young Paul Petrovitch illegitimate, and publicly to marry his miſtreſs Elizabeth Romanovna Vorontzoff. We have ſhewn elſewhere (ſee RUSSIA, n^o 72. *En cycl.*) how this plan, when almoſt ready to be carried into execution, was betrayed to Catharine, who, ever ſince her caballing with the Chancellor Beſtucheff, had reſolved,

Catharine. resolved, by some means or other, to snatch the sceptre from the feeble hand of her husband. At present, we believe she was not acquainted with it; and though she had, she could not now have turned it to her advantage, as her party, ever since the disgrace of Bestucheff, was without a leader of any abilities.

Amid these distractions, caused by the prospect of the death of the empress, and the known hatred of the Grand Duke and Dukes to each other, Count Panin, preceptor to the young prince, devoted himself entirely to Catharine. He wished to see her possessed of all the power of the empire; but he was afraid to proceed to the extremity to which she proposed to go, and to deprive Peter of the name of Emperor. He contrived therefore to procure an apparent reconciliation between the Grand Duke and his consort, as well as between him and his aunt Elizabeth; and he had almost persuaded the silly prince not to assume the sovereign power on the death of the empress, till he should be solemnly invested with it by a decree of the senate. Could he obtain this point, he knew that the power of Peter would be limited, and the authority secured to his wife and his son. He was, however, disappointed. Catharine herself disapproved of this plan, and concurred with the real friends of her husband in advising him "to conform to established custom in assuming the reins of empire."

He had hardly received this advice when word was brought him that the Empress Elizabeth was dead (A); and the courtiers pressed in crowds about him. He accepted them with dignity, received the oaths of the officers of his guard, and seemed at once to have laid aside his weakness. In an hour he got on horseback, traversed the streets of St Petersburg, and distributed money among the multitude and the soldiers. He had been so treated by his aunt, that he could not possibly be grieved at her death; but in paying the last duties to her remains, he betrayed no indecent elation. The first actions of his reign were prudent and patriotic, and such as would have done honour to a greater prince. He appeared to be reconciled to his wife, in whose company he spent much of his time; he recalled from prison and banishment 17,000 persons, some of them of rank and of great talents, who had been the victims of Elizabeth's jealous timidity; he permitted the nobility to bear arms or not at their own discretion, freeing them at the same time from the extreme servitude under which they had been held by his immediate predecessors; and he abolished the *secret committee*, an infamous inquisitorial tribunal, which ever since the reign of the father of Peter the Great had been the chief engine of Russian despotism.

He neglected, however, one thing; which, among the people over whom he was appointed to reign, would have contributed more to the security of his throne than all the wife and beneficent edicts which he had published. He made no preparations to be crowned at Moscow. Instead of complying with this ancient ceremony, and humouring the prejudices of his superstitious subjects, he thought of nothing but of war with Denmark, and of a personal interview with the king of Prussia in Germany. His admiration of that great monarch hur-

ried him indeed into the most extravagant follies. Not Catharine. contented with giving him peace, and entering into an offensive and defensive alliance with him, he had the meanness to solicit a commission in his army, and to accept of the rank of major-general. Of this title he seemed more vain than of that of Emperor of all the Russias. He constantly wore the Prussian uniform; introduced among his troops the Prussian discipline, which, though better than their own, was disagreeable, because it was new, and much more because it was German; and he raised his uncle, a man of no military talents, and a foreigner, to the dignity of generalissimo of the Russian armies; giving him at the same time the particular command of the horse-guards, a body of men which had never before been under any command but that of the supreme head of the empire. Nor did his infatuated predilection for Germany, a country abhorred by the Russians, stop even here: He disbanded the noble guards which had placed Elizabeth on the throne, discontinued the horse-guards from the service which they performed at court, and substituted his Holstein guards in their place.

Whilst he was thus alienating from himself the affections of the army, he contrived to disgust another order of men, whose attachment he should have laboured above all things to retain. He was at pains to shew his preference of the Lutheran faith and worship to the doctrines and ceremonies of the Greek church; he attempted to make some alterations in the dress of the monks; he annexed great part of the possessions of the church to the domains of the crown; and he banished the archbishop of Novogorod, who opposed these innovations; and found himself obliged suddenly to recall him.

He had now returned to his former courses. He shut himself up for whole days with his mistress and drunken companions; he compelled the nobility and ladies of the court to sit in company with buffoons and comedians; he insulted every foreign minister but the ministers of Great Britain and Prussia; and he made no secret of his intention to repudiate the empress, declare Paul Petrovitch illegitimate, and marry the Countess Vorontzoff. Convinced, however, as it would seem, that he could not be a father, he resolved to adopt Prince Ivan, the descendant of the elder brother of Peter the Great, whom Elizabeth had dethroned and confined in prison; to declare him his successor; and to unite him in marriage with the young princess of Holstein Beck, who was then at St Petersburg, and whom he cherished as his daughter.

This inconsistent and weak conduct of the emperor turned the attention of all orders of men to the empress, who made it her sole employment to gain those hearts which he was losing. Instructed from her infancy in the arts of dissimulation, it was not difficult for her to affect, in the sight of the multitude, sentiments the most foreign to her mind. The pupil of the French philosophers put on the air of a bigot to the most superstitious ceremonies of the Greek religion, and treated the ministers of that religion with the profoundest reverence. And whilst her husband was getting drunk

(A) Christmas-day 1761 according to the Russian calendar, or the 5th of January 1762 according to ours.

Catharine. amidst a rabble of buffoons, and disgusting every person of decency who approached him, she kept her court with a mixture of dignity and affability, which attracted to her all who, by capacity, courage, or reputation, were capable of serving her.

Correct, as her public conduct appeared, her private life was not less licentious than formerly. While yet Grand Duchess, she had formed a very tender connection with Gregory Orloff, a man of mean birth, and of no education, but possessed at once of personal beauty and the most daring courage. He had an inferior commission in the artillery, while his two brothers were common soldiers in the regiments of guards. The intrigue which she carried on with him was known only to one of her women named Catharine Ivanovna; nor did Orloff himself for some time suspect the rank of the lady who so lavishly conferred upon him her favours in secret. At last, finding him intrepid and discreet, she discovered herself, unveiled to him all her ambitious designs, and easily prevailed with him and his brothers to enter with zeal into her conspiracy against the emperor. Orloff likewise gained over Bibikoff his friend, a Lieutenant Passick, with other officers; and by their means easily seduced some regiments of the guards. The Princess Dashkoff was strongly attached to Catharine, we believe, from worthy motives, and had frequent meetings with Orloff on the business of the conspiracy, without suspecting that he was so much as known to the empress. Count Panin, too, and the Hetman of the Kofacks, were determined to tumble Peter from the throne; but they were not inclined to go all the lengths proposed by Catharine and her two favourites. Hoping to enjoy the actual power of the empire themselves, they were for declaring Paul Petrovitch emperor in the room of his father, and conferring upon his mother the name and authority only of regent; while the princess and Orloff, knowing the sentiments and wishes of the empress, were resolved to vest her with sovereign power, or to perish themselves in the hazardous attempt.

In the mean time the anniversary of the patron saints of Russia was at hand, when Peter had determined, at the conclusion of the festival, to divorce the empress, shut her up in prison, declare her son illegitimate, and publicly marry his mistress. As they who plan a conspiracy are always more vigilant than those against whom it is directed, the friends of Catharine were carefully informed of all that passed about the emperor, whilst he was kept in total ignorance of their proceedings. It was therefore necessary for them to unite in the same plan, and to carry it quickly into execution; for delay or divisions would involve them all in one common ruin. The empress contrived to bring over the Hetman entirely to her views; and the Princess Dashkoff, by the sacrifice, it has been said, of her charms, found little difficulty in reconciling Count Panin to the same measures. They now agreed to seize the Tzar on his arrival at Peterhoff, an Imperial palace on the shore of the Gulf of Cronstedt, where he proposed to celebrate the approaching festival; and they were waiting impatiently for the moment of action, when all at once their plot was discovered.

Passick, who has been mentioned among the conspirators, had gained the soldiers of the company of guards in which he was a lieutenant; but one of them, who

Catharine. thought that his captain was in the secret, asked that officer one evening, When they were to take up arms against the emperor? The captain, surprised, had recourse to dissimulation, and easily drew from the soldier all that he knew of the conspiracy. It was nine o'clock at night. Passick was put under arrest; but found means to slip into the hands of a man who had been placed as a spy over him by the Princess Dashkoff, a scrap of paper containing these words, "Proceed to execution this instant, or we are undone." The man was desired to carry it to the Hetman, by whom he would be handsomely rewarded; but he hurried with it to the princess, who instantly communicated the intelligence to the other conspirators. She herself put on man's apparel, and hastened to the place where she was accustomed to meet Orloff and his friends; where she found them, as impatient as herself to carry their plot into immediate execution.

During this awful crisis the empress was at Peterhoff, at the distance of 25 versts from St Petersburg; and one of the brothers of Gregory Orloff, named Alexius, undertook to find her out, whilst he himself, with his other brother and Bibikoff his friend, repaired to the barracks for the purpose of instructing the soldiers of their party how to act on the first signal. Alexius Orloff carried with him a short note from the Princess Dashkoff, but neglected to deliver it; and the empress, being suddenly roused from a sound sleep, was much alarmed, when she saw at the side of her bed a soldier of whom she knew nothing. Her alarm was increased when the stranger said, "Your majesty has not a moment to lose; get ready to follow me;" and instantly disappeared. She rose, however, and calling her woman Ivanovna, they disguised themselves in such a manner that they could not be known by the sentinels about the palace; and the soldier returning, they hurried with him to a coach which was waiting at the garden gate. Orloff took the reins, but drove with such fury that the horses soon fell down; and they were obliged to travel part of the way on foot. They had not, however, gone far, when they met a light country cart; and she who was aspiring to the throne of the greatest empire in the world, was glad to enter the capital of that empire in this humble vehicle.

It was seven in the morning when she arrived in St Petersburg: and to the soldiers, who gathered about her in great numbers, she said, that "her danger had driven her to the necessity of coming to ask their assistance; that the Tzar had intended, that very night, to put her and her son to death; and that she had so great confidence in their dispositions, as to put herself entirely into their hands." They immediately shouted, "Long live the empress!" And the chaplain of one of the regiments fetching a crucifix, received their oaths of fidelity.

The troops, however, were not unanimous in this revolt. Though Gregory Orloff was treasurer of the artillery, and well enough beloved by the soldiers, that corps refused to follow him until he should produce the orders of Villebois their general: and that officer, withheld either by fidelity to the emperor or by fear, presumed to speak to Catharine of the obstacles which yet remained for her to surmount; adding, that she ought to have foreseen them. She haughtily replied, that "she had not sent for him to ask what she ought to have foreseen,

Catharine. foreseen, but to know how he intended to act." "To obey your Majesty," returned Villebois; and putting himself at the head of his regiment, he immediately joined the conspirators. So ripe indeed were the minds of all men for this revolt, that in the space of two hours the empress found herself surrounded by 2000 warriors, together with great part of the inhabitants of Peterburgh: and with that numerous train of attendants she repaired to the church of Kasan, where the archbishop of Novogorod, setting the Imperial crown on her head, proclaimed her sovereign of all the Russias, declaring, at the same time, Paul Petrovitch her successor.

Matters had now proceeded by much too far to admit of any compromise between Catharine and her husband: but had the infatuated Tzar put his affairs wholly into the hands of Marshal Munich, that intrepid veteran would have tumbled the empress from her throne almost as quickly as she had got possession of it. He acted, however, a very different part. Upon receiving intelligence of what had been done at St Petersburg, he asked indeed the Marshal's advice, but suffered himself to be guided by his mistress and timid companions. Through their terrors and his own irresolution opportunities were lost which could never be recovered; for though his Holstein guards, with tears in their eyes, swore that they were all ready to sacrifice their lives in his service, and though the old Marshal offered to lead them against the rebels, saying to the emperor, "I will go before you, and their swords shall not reach you till they have pierced my body," he was persuaded to treat with the empress, to acknowledge his misconduct, and to offer to share with her the sovereign power. At last he was weak enough to abandon his troops, and to surrender at discretion to his consort; whose creatures hurried him from Oranienbaum to Peterhoff, stripped him of all his clothes, and, after leaving him for some time in his shirt, a butt to the outrages of an insolent soldiery, threw over him an old morning-gown, and shut him up alone, with a guard at the door of his wretched apartment. On the 29th of June, O. S.* 1762, Count Perin was sent to him by the empress; and after a long conference, prevailed with him to write and sign a solemn resignation of his crown, and a declaration of his utter incapacity to govern so great an empire.

The revolution was now complete, and Peter seemed to enjoy some composure of mind; but in the evening he was carried a prisoner to Ropscha, a small Imperial palace, at the distance of 20 versts from Peterhoff, where he was murdered on the 17th of July, just one week after his deposition. Of the manner of his death different accounts have been given. By some he is said to have been poisoned; by others, to have been strangled by one of the Orloffs; and a few have thought that he perished by the same means as Edward II. of England. Whether the empress was accessory to his death is not known; though it is certain, that so far from making any inquiry after his murderers, she affected to believe that he had died naturally of the *piles*!

The first care of Catharine was to reward those who had been the principal actors in the revolt. Panin was made prime minister; the Orloffs received the title of Count; and the favourite Gregory was appointed lieutenant-general of the Russian armies, and knight of the order of St Alexander Nefsky, the second order of the empire. Several officers of the guards were promoted,

of whom 24 received considerable estates; and among the soldiers, whom she treated with the greatest affability, brandy and beer were liberally distributed. The Chancellor Bestucheff, who had been the most inveterate enemy of Peter, was recalled from his exile, restored to his rank of field-marshal, and had an annual pension settled upon him of 20,000 rubles. To the friends of the emperor she behaved with great moderation. Prince George, whom he had constituted Duke of Courland, was indeed obliged to renounce his title; but the administration of Holstein was committed to him, and he ever after served the empress with zeal and fidelity.

The news of the revolution was soon spread over Europe; and none of the sovereigns, though they knew by what steps Catharine had mounted the throne, hesitated for a moment to acknowledge her title. She was not, however, at perfect ease in her own mind; nor was her right recognized by all her subjects. Though she published manifestoes, setting forth the intentions of the late emperor towards her and her son, which made resistance necessary; though in these papers she attributed her elevation to the wishes of her people and the providence of God; and though she called upon all who were sincerely attached to the orthodox faith of the Greek church, to consider the sudden death of Peter as the judgment of heaven in favour of the revolution—yet in the distant provinces no exultations were heard; both soldiers and peasants observed a gloomy silence. Even at Moscow, so great was the disaffection to Catharine's government, that it was some time before she could venture to go to that city to be crowned; and she found in it at last so cold a reception, that she very quickly returned to St Petersburg.

Nor was this the only cause of her uneasiness. The connection between Orloff and her became visible, and gave just offence to her other friends. The princess of Dashkoff first perceived it; and when she presumed to expostulate with the empress on the meanness and impudence of her passion, she was banished from the court to Moscow. Count Panin and the Hetman saw with indignation that they had dethroned the grandson of Peter the Great, to aggrandise a rude and low-born upstart. Cabals and conspiracies were entered into by high and low, both against Catharine and against her favourite; and it required all her abilities and firmness to preserve at once her throne and her lover. On one occasion she hoped to obtain from the Princess Dashkoff sufficient proof that Panin and the Hetman of the Kosacks were concerned in a plot which had just been discovered; and with this view she wrote to her a letter of four pages, filled with the most tender epithets and the most magnificent promises, conjuring her in the name of their long-standing friendship, to reveal what she knew of the recent conspiracies. With becoming magnanimity, the princess replied, "Madam, I have heard nothing; but if I had heard any thing, I should take good care how I spoke of it. What is it you require of me? That I should expire upon a scaffold? I am ready to mount it."

Catharine, despairing of conquering such a spirit, attempted to attach to her those whom she dared not to punish. Some of the inferior conspirators were banished to Siberia, while Panin and the Hetman, whom she most dreaded, received additional marks of her favour. In the mean time, to gain the affections of the people,

Catharine. at large, she paid the utmost attention to the administration of justice; formed magnificent establishments for the education of the youth of both sexes; founded hospitals for orphans, for the sick, and for lying-in women; invited foreigners of all nations, possessed of any merit, to settle in different parts of her vast territories; increased the naval force of the empire; and gave such encouragement to the cultivation of every elegant and useful art, that in the short space of a year and a half from her accession to the throne, the national improvement of Russia was visible.

In the good fortune and glory of Catharine, no one rejoiced more sincerely than Count Poniatowsky. He approached towards the confines of Russia, and wrote to her in the tenderest style of congratulation, requesting permission to pay his respects to her in the capital of her empire. It is not improbable that he flattered himself with the hopes that she would give him her hand in marriage, and thus raise him to the throne of the Tzars; but she had promised to the Empress Elizabeth, that she would never again see the count; and to that promise she at present adhered. She wrote to him, however, in the most affectionate terms; and tho' she gave him no encouragement to repair to St Petersburg, she assured him that she had other prospects in view for his aggrandisement, and that he might depend upon her perpetual friendship: and she soon appeared to be as good as her word. On the death of Augustus III. she raised her former favourite to the throne of Poland, in opposition to the wishes of the courts of Vienna and Versailles, as well as of a great majority of the Polish nobles. She defeated the intrigues of the two foreign courts by more skilfully conducted intrigues of her own; and by pouring her armies into the republic, she so completely overawed the nuncios, that Poniatowsky was chosen by the unanimous suffrages of the diet which met for the election of a sovereign; and, on the 7th of September 1764, was proclaimed King of Poland and Grand Duke of Lithuania, by the name of Stanislaus Augustus.

Whilst she was thus disposing of foreign kingdoms, she was kept under perpetual dread of being tumbled from the throne of her own vast empire. Her want of title to that throne was now seen by all ranks of her subjects: the good qualities of Peter the third were remembered, and his failings and faults forgotten. His fate was universally lamented; and, except the conspirators, who may be said to have embued their hands in his blood, there was hardly a Russian who did not regret that the sovereignty had passed from the ancient family of the Tzars to a foreigner, allied only by marriage to the blood royal. Even the conspirators themselves had lost much of their regard for Catharine. The princess of Dashkoff was a second time banished to Moscow; and, to magnify her own importance, she spoke freely of the means by which the empress, whom she accused of ingratitude, had been raised to the throne. The inhabitants of Moscow, who never favoured the usurpation, were thus made ripe for a revolt. At St Petersburg, Count Panin felt himself uneasy under the predominant influence of the favourite, and tried in vain to divert Catharine's affections to a new object. She received a few secret visits from a handsome young man, and then appointed him to a lucrative and honourable employment in some distant province of the empire;

Catharine. when Orloff recovered his former ascendancy, which through his own carelessness he had nearly lost. In this state of the public mind, conspiracies were very frequent; and as the general object of them was to place on the throne Prince Ivan, who was again languishing in the dungeon from which Peter had taken him, the empress had given to his guard an order, signed by her own hand, to put that unfortunate prince to death, should any attempt be made to liberate him from his prison. An attempt was made by a very inferior officer, as some have supposed, by the instructions of Catharine, and her bloody order was instantly obeyed. The assassins were rewarded, and promoted in the army; but the officer who attempted to rescue the prince was condemned to death, and suffered unexpectedly the sentence of the law. The brothers and sisters of Ivan, who had been kept in a prison different from his, were sent to Denmark; and, to provide them with necessaries suitable to their rank, the empress made them a present of 200,000 rubles, and paid annually, to the maintenance of their dignity, a pension of thirty thousand.

The throne of Catharine was now firmly established, by the death or renunciation of every person who was descended of the imperial family; and she had leisure to turn her thoughts to the aggrandisement of the empire. It was soon seen that this was the object which she had in view when she raised Count Poniatowsky to the throne of Poland, and that she was not actuated on that occasion by any remains of her former attachment. We have elsewhere shewn (see POLAND, *Encycl.* n° 98 — 115) under what pretences she invaded the kingdom of him who had formerly been one of her most favoured lovers, and by what means she annexed great part of it to the territories of Russia. But it is not through her wars that in this article we mean to trace her character: It is not as a sovereign and heroine that her life is entitled to a place in a general repository of arts, sciences, and miscellaneous literature, but as a patroness of art and of science, and as the legislatrix of a vast empire, who employed all her talents and all her power for the civilization of a great part of the human race.

Under the article RUSSIA (*Encycl.*), we have mentioned the famous *code of laws for a great empire*, and the proposed *convention of deputies from all the classes*, which Catharine and the Princess Dashkoff so artfully employed as means to bring about the revolution which seated the former on the throne. The states actually met in the ancient capital of the empire, and the sovereign's instructions for framing a new code of laws was read amidst reiterated bursts of applause. All present extolled the sagacity, the wisdom, the humanity of the empress; but fear and flattery had a greater share in these exclamations than any just knowledge of the subject. The deputies of the Samoides alone had the courage to speak freely. One of them stood up, and, in the name of himself and his brethren, said, "We are a simple and honest people. We quietly tend our reindeer. We are in no want of a new code; but make laws for the Russians, our neighbours, that may put a stop to their depredations." The following sittings did not pass so quietly. A debate about the liberation of the boors was carried on with such warmth, that fatal consequences were to be apprehended; and the deputies were dismissed to their respective provinces in the

Catharine, the manner which we have elsewhere related. Previous, however, to the dissolution of this assembly, the members were required to signalize the meeting by some conspicuous act of gratitude; and, by a general acclamation, the titles of GREAT, WISE, PRUDENT, and MOTHER OF THE COUNTRY, were decreed to the empress. With assumed modesty she accepted only of the last, "as the most benign and glorious recompence for her labours and sollicitudes in behalf of a people whom she loved."

For that people she did indeed labour, and labour most usefully. She introduced into the administration of justice the greatest reformation of which the half-civilized state of Russia would perhaps admit. She spared neither trouble nor expence to diffuse over the empire the light of science, and the benefits of useful and elegant arts; and she protected, as far as she could, the poor from the oppressions of the rich. About the middle of 1767, she conceived the idea of sending several learned men to travel through the interior of her vast dominions, to determine the geographical position of the principal places, to mark their temperature, and to examine into the nature of their soil, their vegetable and mineral productions, and the manners of the people by whom they were inhabited. To this employment she appointed Pallas, Gmelin, Euler, and many others of the highest eminence in the republic of letters; from whose journals of these interesting travels large additions have been made to the general stock of useful knowledge. This survey of the empire, and the maps made from it, had Catharine done nothing else, would alone have been sufficient to render her name immortal. Well convinced in her own mind, that it is not so much by the power of arms, as by precedence in science, that nations obtain a conspicuous place in the annals of the world, with a laudable zeal she encouraged artists and scholars of all denominations. She granted new privileges to the two academies of sciences and the arts; encouraged such of the youth as had behaved well in these national institutes, to travel for farther improvement over Europe, by bestowing upon them, for three years, large pensions to defray their expence; and, to remove as much as possible the Russian prejudice against all kinds of learning, she granted patents of nobility to those who, during their education, had conducted themselves with propriety, and become proficient in any branch of useful or elegant knowledge. Still farther to encourage the fine arts in her dominions, she assigned an annual sum of 5000 rubles for the translation of foreign literary works into the Russian language.

In the year 1768, the small-pox raged at St Petersburg, and proved fatal to vast numbers of all ranks and of every age. The empress was desirous to introduce the practice of inoculation among her subjects; and resolved to set the example by having herself and her son inoculated. With this view, she applied for a physician from England: and Dr Thomas Dimsdale of Hertford being recommended to her, he repaired with his son to the capital of Russia, where he inoculated first the empress, then the grand duke, and afterwards many of the nobility. The experiment proving successful, he was created a baron of the empire, appointed actual counsellor of state, and physician to her imperial majesty, with a pension of L. 500 sterling a-year, to

be paid him in England, besides L. 10,000 which he immediately received. So popular was the empress at this period, that, by a decree of the senate, the anniversary of her recovery from the small pox was enjoined to be celebrated as a religious festival; and it has ever since been observed as such.

She was now engaged in war with the Turks of which a sufficient account for a work of this nature has been given under the title TURKEY (*Encycl.*); but there was one transaction of her and her friends, of which no mention was made in that article, though it is of importance to him who would form a just estimate of her personal character.

We have noticed the sensuality of the empress Elizabeth. She bore three children to the grand veneur Alexey Gregorievitch Razumoffsky, to whom, indeed, she is said to have been clandestinely married. Of these children the youngest was a girl, brought up under the name of Princess Tarrakanoff. Prince Radzivil, who has been mentioned in the article POLAND (*Encycl.*), irritated at Catharine's cruelties to his countrymen, conceived the project of placing the young princess on the throne of her ancestors; and, having gained over the persons to whom her education was intrusted, he carried her off to Rome as a place of safety. Catharine, in return, seized his large estates; and he and the princess were reduced to extreme poverty. Radzivil repaired to Poland in order to learn what could be done to forward his great enterprise; and scarcely had he arrived there when an offer was made to restore to him his possessions, upon condition of his carrying his ward to St Petersburg. This he refused: but had the baseness to promise, that he would give himself no farther concern about the daughter of Elizabeth; and he was put in possession of all his estates.

By the instructions of the empress, Alexius Orloff, who nominally commanded the Russian fleet at the Dardanelles, repaired to Rome, got access to young Tarrakanoff, and found means to persuade her that all Russia was ready to revolt from Catharine, and place her on the throne of her mother. To convince her of his sincerity, he pretended to feel for her the tenderest and most respectful passion; and the unsuspecting lady was induced to accept of him as a husband. The Russian who had assassinated the grandson of Peter the Great, did not hesitate to seduce and betray his grand daughter. Under pretence of having the marriage ceremony performed according to the rites of the Greek church, he suborned some subaltern villains to personate priests and lawyers; thus combining profanation with imposture against the unprotected and too confident Tarrakanoff.

Having been treated for some days, both at Rome and at Leghorn, with all the respect due to a sovereign, the unsuspecting princess expressed a wish to go on board a Russian ship of war. This was just what Orloff wanted. Attended by a numerous and obsequious train, she was rowed from the shore in a boat with magnificent ensigns, hoisted upon the deck of the ship in a splendid chair, and immediately handcuffed. In vain did she throw herself at the feet of her pretended husband, and conjure him by every thing tender which had passed between them. She was carried down into the hold; the next day the vessel sailed for St Petersburg; where, upon her arrival, the princess was shut up in the fortrefs; and what became of her since was

never

Catharine. never known. Such were the means which Catharine scrupled not to employ in order to get rid of all pretenders to her throne.

Soon after this service rendered to her by Alexius Orloff, she dismissed his brother Gregory from her favour, and connected herself with Vassiltchikoff, a sub-lieutenant of the guards. The former favourite had indeed become insolent, and, as Catharine thought, ungrateful. He aspired to nothing less than the throne. From love to himself, and to a son which she had born to him, she offered to enter into a secret marriage; but with this proposal the proud prince (A) was not satisfied, and hoped that his refusal would impel her to receive him publicly as her husband and partner in power. He was mistaken. She divested him of all his employments; but gave him a pension of 150,000 rubles, a handsome service of plate, and an estate with 6000 peasants upon it; and, thus enriched, he set out upon a journey through various parts of Europe. He returned, however, much sooner than was expected; the new favourite was handsomely rewarded, and sent to a distance; Orloff was restored to all his offices, and his baleful influence was again felt.

He attempted to persuade the empress to dismiss Panin from the court; but the grand duke interposed in behalf of his old preceptor; and, for once, Catharine listened to the entreaties of her son. When a dreadful rebellion, under a Kosak of the name of Pugethoff, who pretended to be Peter III. escaped from his assassins, was shaking the throne to its foundation—the influence of Orloff was such as to prevent the empress, for some time, from employing her ablest general against the rebels, because that general was Panin, brother to the minister. Danger, however, at last prevailed over the favourite: Panin was sent against Pugethoff; the rebellion was crushed; and Catharine found leisure to give something like a legal constitution to the empire. In that work, the laws and regulations established for the government of the various provinces, and for the equitable administration of justice through the whole of her vast dominions, evinces the greatest wisdom and sagacity in their author, as well as a proper regard to the practicable liberties and rights of men. In the capital, she established the most perfect police, by which the internal tranquillity of a great city was, perhaps, ever maintained; and whilst her private conduct was far from correct, she was acting in the capacity of sovereign, so as to deserve, indeed, the appellation of *Mother of her people*.

To follow her through all her wars and intrigues with foreign courts, would swell this article to the size of a volume. Such a narrative, too, belongs rather to the history of Russia than to the memoirs of Catharine; in which it is the business of the biographer to develop the private character of the woman, rather than to detail the exploits of the sovereign. Her partition of Poland, and afterwards the annihilation of it as an independent republic; her encroachments on the territories of the grand signior; her formation of the armed neutrality; the influence which she maintained over the courts of Sweden and Denmark; and the art with which she threw the weight of Russia sometimes into

the scale of Austria, and sometimes into that of Prussia, just as the interests of her own dominions required the one or the other to preponderate—shew how admirably she was qualified to guide the helm of a great empire in all its transactions with foreign states. We speak not of the equity of her proceedings; for it must be confessed, that equity formed no barrier against her ambition; and that she never failed to subjugate those whom she pretended to take under her protection. Her ruling passion was to enlarge her own territories, already so very extensive; and, for the attainment of that object, she contrived the most judicious plans, which she executed with vigour. In this part of her conduct, however, she has been equalled by other monarchs; but in the zeal and the wisdom with which she endeavoured to introduce among her half-savage subjects the blessings of knowledge and industry, she stands unrivalled, except, perhaps, by her predecessor Peter the Great. Of this we need bring no other proof, in addition to what has been already stated, than that she founded in St Petersburg alone thirty-one seminaries, where 6800 children of both sexes were educated at the annual expence to the government of 754,335 rubles. She superintended herself the education of her grandchildren, and wrote for them books of instruction. If it be true, that “every man acquainted with the common principles of human action, will look with veneration on the writer who is at one time combating Locke, and at another making a catechism for children in their fourth year;” with what veneration should we look upon the empress of Russia, could we forget the means by which she obtained that elevation from which she frequently descended for a similar employment: This she did, not for her own descendants alone, but also for the children of others; of whom she had always a great number in her apartments, who shared in the instruction given to her grandchildren, and whose caresses she returned with extreme complaisance.

Her greatest weakness was surely that gross passion which her panegyrists have dignified with the name of love; but to such an appellation it had no claim, if love be any thing more than a sexual appetite. Besides Gregory Orloff, she had not fewer than ten favourites after the death of her husband; and of these she seems to have felt a refined affection for none but Lanskoi, a young Pole of a very ancient family, and of elegant manners, and the famous Potemkin, to whom she is said secretly to have given her hand, and who preserved her friendship, if not her affection, to the end of his life. To Lanskoi, whose education had been much neglected, she condescended to become preceptor; and, as he made great progress in the acquisition of useful knowledge, she admired in him her own creation. Potemkin, though not amiable, deserved her favour for the fidelity and abilities with which he served her, both in the council and in the field; and in him, when she had ceased to look on him with the eyes of love, she respected the intriguing politician and intrepid commander, who had formed plans for driving the Turks out of Europe, and setting her on the throne of Byzantium. Her other favourites had nothing to recom-

mend

(A) She had some time before obtained for him a patent, creating him a prince of the Roman empire.

Catharine. mend them but masculine beauty and corporeal strength. One of them, however, thought it necessary to have a library in the grand house, of which the empress, upon receiving him into favour, had made him a present; and desired the principal bookseller to fill his shelves. The man asked him what books he would please to have. "You understand that better than I (replied the favourite); that is your business. You know the proper assortments; I have destined a large room to receive them. Let there be large books at the bottom, and smaller and smaller up to the top; that is the way they stand in the empress's library!" In the conversation of such men the cultivated mind of Catharine could enjoy no interchange of sentiments.

We know not whether that more than Asiatic magnificence, which she displayed on every public occasion, should be considered as an instance of weakness or of wisdom. If she delighted in balls, and masquerades, and sumptuous entertainments, and dress loaded with jewels, and every kind of splendid ornament, for their own sakes, she betrayed a weakness unworthy of that sovereign who held in her hand the balance of Europe, and at whose nod the greatest powers of Asia trembled: but if she introduced such splendor into her court merely to divert the attention of the Russians from the means by which she got possession of the throne, and to wean them from their own savage and slovenly manners; even this may perhaps be considered as one of her most masterly strokes in politics.

Her ambition was boundless; but, if such a phrase may be allowed, it was not always true ambition. When the French republic had established itself on the ruins of monarchy, and was propagating new theories of government through all Europe, true ambition would surely have led the autocratrix of the north to unite her forces with those of the coalesced powers, in order to crush the horrid hydra, before its anarchical principles could be introduced among her own barbarous subjects. Such would certainly have been the advice of her favourite Potemkin, who longed to lead a Russian army into France, even before the murder of the unfortunate Lewis. That general, however, had died in October 1791; and when Britain, Austria, and Prussia, were leagued against the new republic, Catharine looked coolly on, in hopes, it is probable, of availing herself of their weakness, when exhausted by a long and bloody war. She gave refuge, indeed, in her dominions to many emigrants from France, and sent a squadron of ships to co-operate with the navy of England: but in this last measure she regarded merely her own immediate interest; for her crazy ships were repaired by British carpenters at the expence of the British government, and her officers had an opportunity of learning the evolutions of the British navy. She had likewise other prospects in view when she lent to the allies this slender aid. She meditated a new war with Turkey; and, depending upon meeting with no opposition, if she should not receive assistance from England and Austria, she flattered herself with accomplishing her darling project of driving the Ottomans out of Europe, and of reigning in Constantinople. But she was disappointed. On the morning of the 9th of November 1796, she was seized with what her principal physician judged a fit of apoplexy; and, at 10 o'clock in the evening of the following day, expired, in the 68th year of her age, leaving

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behind her the character of one of the greatest sovereigns that ever swayed a sceptre.

After this long detail of the incidents of her life, it is needless to inform the reader that Catharine II. had no religion, and, of course, no principles of morality, which could induce her in every instance to do to others as she would have them do to her. She was a professed disciple of the French philosophers; by some of whom she was ridiculed, and by others cheated. The incense which she paid to the genius of Voltaire did not hinder him from frequently breaking his jests upon the autocratrix of Russia and her successive favourites; and Diderot, whom she caressed, sold to her an immense library, when he possessed hardly a book, and was obliged to ransack Germany and France for volumes to enable him to fulfil his bargain. Such is the friendship, and such the gratitude, which subsists among the amiable pupils of nature, and the philanthropic advocates for the rights of man.

CAUDA *Capricorni*, a fixed star of the fourth magnitude, in the tail of Capricorn; called also, by the Arabs, *Dineb Algedi*; and γ by Bayer.

CAUDA *Ceti*, a fixed star of the third magnitude; called also, by the Arabs, *Dined Kaetos*; marked β by Bayer.

CAUDA *Cygni*, a fixed star of the second magnitude, in the Swan's tail; called by the Arabs *Dineb Adigege*, or *Eldegiagich*; and marked α by Bayer.

CAUDA *Delphini*, a fixed star of the third magnitude, in the tail of the Dolphin; marked ϵ by Bayer.

CAUDA *Draconis*, or Dragon's tail, the moon's southern or descending node.

CAUDA *Leonis*, a fixed star of the first magnitude, in the Lion's tail; called also, by the Arabs, *Dineb Eleced*; and marked β by Bayer. It is called also *Lucidæ Cauda*.

CAUDA *Ursæ Majoris*, a fixed star of the third magnitude, in the tip of the Great Bear's tail; called also, by the Arabs, *Alalioth*, and *Benenath*; and marked η by Bayer.

CAUDA *Ursæ Minoris*, a fixed star of the third magnitude, at the end of the Lesser Bear's tail; called also the *Pole Star*, and, by the Arabs, *Alrukabab*; and marked α by Bayer.

CAUSE has been defined, we think, with accuracy in the Encyclopædia, and the doctrine stated which we believe to be true. Objections however have been made to that doctrine, of which we have endeavoured to remove some, under the title ACTION, in this Supplement; and the doctrine itself has been well illustrated (at least such is our opinion) in the supplementary article ASTRONOMY. We have, therefore, very little to add here on the subject of causes, though it is the most important subject which can employ the mind of man. What is the relation between a physical cause and that which is termed its effect—between heat, for instance, and the fusion of metals? Is it a *necessary connection*, or only a *conjunction*, discovered by experience to be *constant*?

If by *necessary connection* be meant that kind of connection of which the contrary cannot be conceived, we do not think that the connection of any physical cause with its effect can be called necessary. We see no difficulty in conceiving, that fire, instead of fusing gold, might fix mercury. This *may* indeed be impossible;

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and

Cauda,
Cause.

Cause,
Center.

and we might perhaps see the impossibility, did we as completely know the nature of fire and of metals, as we know the relations of pure geometry. We know that the three angles of a plain triangle cannot possibly be either greater or less than two right angles; for in this comparison nothing is hid from our mental view. We do not, however, perceive the impossibility of mercury being fixed, as clay is hardened, by heat; for of *heat*, and mercury, and clay, we know very little, and that little is the offspring of experience.

But if the connection between cause and effect be not necessary, are we not deprived of the means of demonstrating the great fundamental truth of religion? We have nowhere said, that the connection between cause and effect is not necessary; but only, that we do not perceive the necessary connection between what are called *physical causes* and their effects. That every event is, and must be, brought about by *some cause* or *some agency*, we hold to be a self-evident truth, which no man can deny who understands the terms in which it is expressed; but what or where the agency is, we can very seldom, if ever, know, except when we think of our own voluntary actions. When a change is observed, we cannot doubt of its being produced by something: either the thing changed is animated, and has produced the change by its own agency, just as we move our heads and legs by an act of volition; or if it be inanimated, and of itself incapable of agency, the change has been produced by something external, denominated a *cause*. But all external causes, which are not likewise agents, in the proper sense of the word, may be traced, we think, as effects up to some agency; and therefore, in our opinion, there is no real, ultimate, efficient cause but mind, or that which is endued with power. In proof of this doctrine, if it need any proof, we can only refer to what has been said elsewhere on our notions of *power* and of *physical causes*. See (*Encycl.*) METAPHYSICS, n^o 109, &c.—PHILOSOPHY and PHYSICS, *passim*—and (*Suppl.*) ACTION and ASTRONOMY.

I
Definition.

CENTER, or CENTRE, a word borrowed from the French name *centre* or *centre*, given to the frame of timber, by which the brick or stone of arched vaulting is supported during its erection, and from which it receives its form and curvature.

2
Purpose of
this article.

It is not our intention to describe the variety of constructions which may be adopted in easy situations, where the arches are of small extent, and where sufficient foundation can be had in every part of it for supporting the frame. In such cases, the frequency of the props which we can set up dispenses with much care; and a frame of very slight timbers, connected together in an ordinary way, will suffice for carrying the weight, and for keeping it in exact shape. But when the arches have a wide span, and consequently a very great weight, and when we cannot set up intermediate pillars, either for want of a foundation in the soft bottom of a river, or because the arch is turned between two lofty piers, as in the dome of a stately cathedral—we are then obliged to rest every thing on the piers themselves; and the framing which is to support our arch before the key-stone is set, must itself be an arch, depending on the mutual abutment of its beams. One should think that this view of the construction of a centre would offer itself at the first, naturally derived from the erection it was to assist: but it has not been so. When intermedi-

Center.

ate pillars were not employed, it was usual to frame the mould for the arch with little attention to any thing but its shape, and then to cross it and recross it in all directions with other pieces of timber, till it was thought so bound together that it could be lifted in any position, and, when loaded with any weight, could not change its shape. The frame was then raised in a lump, like any solid body of the same shape, and set in its place. This is the way still practised by many country artists, who, having no clear principles to guide them, do not stop till they have made a load of timber almost equal to the weight which it is to carry.

But this artless method, besides leading the employer into great expence, is frequently fatal to the undertaker, from the unskilfulness of the construction. The beams which connect its extremities are made also to support the middle by means of posts which rest on them. They are therefore exposed to a transverse or cross strain, which they are not able to bear. Their number must therefore be increased, and this increases the load. Some of these cross strains are derived from beams which are pressed very obliquely, and therefore exert a prodigious thrust on their supports. The beams are also greatly weakened by the mortises which are cut in them to receive the tenons of the crossing beams: and thus the whole is exceedingly weak, in proportion to what the same quantity of timber may be made by a proper disposition of its parts.

The principles from which we are to derive this disposition are the general mechanical principles of carpentry, of which we have given some account in that article. These furnish one general rule: When we would give the utmost strength possible to a frame of carpentry, every piece should be so disposed that it is subject to no strain but what either pushes or draws it in the direction of its length: and, if we would be indebted to timber alone for the force or strength of the centre, we must rest all on the first of these strains; for when the straining force tends to *draw* a beam out of its place, it must be held there by a mortise and tenon, which possesses but a very trifling force, or by iron straps and bolts. Cases occur where it may be very difficult to make every strain a thrust, and the best artists admit of ties; and indeed where we can admit a tie-beam connecting the two feet of our frame, we need seek no better security. But this may sometimes be very inconvenient. When it is the arch of a bridge that we are to support, such a tie-beam would totally stop the passage of small craft up and down the river. It would often be in the water, and thus exposed to the most fatal accidents by freshes, &c. Interrupted ties, therefore, must be employed, whose joint or meetings must be supported by something analogous to the king-posts of roofs. When this is judiciously done, the security is abundantly good. But great judgment is necessary, and a very scrupulous attention to the disposition of the pieces. It is by no means an easy matter to discern whether a beam, which makes a part of our centre, is in a state of compression or in a state of extension. In some works of the most eminent carpenters even of this day, we see pieces considered as struts (and considerable dependence had on them in this capacity), while they are certainly performing the office of tie-beams, and should be secured accordingly. This was the case in the boldest centre (we think) that has been

3
General
principles
of construction.

Center. been executed in Europe, that of the bridge of Orleans, by Mr Hupeau. Yet it is evidently of great consequence not to be mistaken in this point; for when we are mistaken, and the piece is stretched which we imagine to be compressed, we not only are deprived of some support that we expected, but the expected support has become an additional load.

4 How to distinguish a strut from a tie. To ascertain this point, we may suppose the piers to yield a little to the pressure of the archstones on the centre frames. The feet, therefore, fly outwards, and the shape is altered by the sinking of the crown. We must draw our frame anew for this new state of things, and must notice what pieces must be made longer than before. All such pieces have been acting the part of tie-beams.

But a centre has still another office to sustain; it must keep the arch in its form; that is, while the load on the centre is continually increasing, as the masons lay on more courses of arch stones, the frame must not yield and go out of shape, sinking under the weight on the haunches, and rising in the crown, which is not yet carrying any load. The frame must not be supple; and must derive its stiffness, not from the closeness and strength of its joints, which are quite insignificant when set in competition with such immense strains, but from struts or ties, properly disposed, which hinder any of the angles from changing its amplitude.

5 How to secure stiffness and strength. It is obvious, from all that has been said, that the strength and stiffness of the whole must be found in the triangles into which this frame of carpentry may be resolved. We have seen that the strains which one piece produces on two others, with which it meets in one point, depends on the angles of their intersection; and that it is greater as an obtuse angle is more obtuse, or an acute angle more acute. And this suggests to us the general maxim, "to avoid as much as possible all very obtuse angles." Acute angles, which are not necessarily accompanied by obtuse ones, are not so hurtful; because the strain here can never exceed the straining force; whereas, in the case of an obtuse angle, it may surpass it in any degree.

Such are the general rules on this subject. Although something of the mutual abutment of timbers, and the support derived from it, has been long perceived, and employed by the carpenters in roofing, and also (doubtless) in the forming of centres, yet it is a matter of historical fact, that no general and distinct views had been taken of it till about the beginning of this century, or a little earlier. Fontana has preserved the figure of the frames on which the arches of St Peter's at Rome were turned. The one employed for the dome is constructed with very little skill; and those for the arches of the nave and transepts, though incomparably superior, and of considerable simplicity and strength, are yet far inferior to others which have been employed in later times. It is much to be regretted that no trace remains of the forms employed by the great architect and consummate mechanician Sir Christopher Wren. We should doubtless have seen in them every thing that science and great sagacity could suggest. We are told, indeed, that his centering for the dome of St Paul's was a wonder of its kind; begun in the air at the height of 160 feet from the ground, and without making use of even a projecting cornice whereon to rest it.

The earliest theory of the kind that we have met

with, that is proposed on scientific principles, and with the express purpose of serving as a lesson, are two centres by Mr Pitot of the Academy of Sciences, about the beginning of this century. As they have considerable merit (greatly resembling those employed by Michael Angelo in the nave of St Peter's), and afford some good maxims, we shall give a short account of them. We crave the excuse of the artists if we should employ their terms of art somewhat awkwardly, not being very familiarly acquainted with them. Indeed, we observe very great differences, and even ambiguity, in the terms employed.

What we shall describe under the name of a *centre* is (properly speaking) only one frame, truss, or rib, of a centre. They are set up in vertical planes, parallel to each other, at the distance of 5, 6, 7, or 8 feet, like the trusses or main couples of a roof. Bridging joists are laid across them.—In smaller works these are laid sparingly, but of considerable scantling, and are boarded over; but for great arches, a bridging joist is laid for every course of archstones, with blockings between to keep them at their proper distances. The stones are not laid immediately on these joists, but beams of soft wood are laid along each joist, on which the stone is laid. These beams are afterwards cut out with the chissel, in order to separate the centre from the ring of stones, which must now support each other by their mutual abutment.

7 The centre is distinguishable into two parts, ALLB (fig. 1.) and LDL, which are pretty independent of each other, or at least act separately. The horizontal STRETCHER LL cuts the semicircle ADB half way between the spring and the crown of the arch; the arches AL, LD, being 45° each. This stretcher is divided in the same proportion in the points G and H; that is, GH is one half of LL, and LG, HL are each one-fourth of LL nearly. Each end is supported by two STRUTS EI, GI, which rest below on a SOLE or BED properly supported. The interval between the heads of the struts GI, HK is filled up by the STRAINING BEAM GH, abutting in a proper manner on the struts (see CARPENTRY, *Supplement*). The extremities L, L, are united in like manner by butting joints, with the heads of the outer struts. The ARCH MOULDS AP, BP, are connected with the struts by cross pieces PQ, which we shall call BRIDLES, which come inwards on each side of the struts (being double), and are bolted to them. This may be called the lower part of the frame. The upper part consists of the king post DR, supported on each side by the two struts or braces ML, ON, mortised into the post, and also mortised into the stretcher, at the points L, N, where it is supported by the struts below. The arches LD, LD are connected with the struts by the bridles PQ, in the same manner as below.

8 There is a great propriety in many parts of this arrangement. The lower parts or haunches of the arch press very lightly on the centres. Each archstone is lying on an inclined plane, and tends to slide down only with its relative weight; that is, its weight is to its tendency to slide down the joint as radius to the sine of elevation of the joint. Now it is only by this tendency to slide down the joint that they press on the centering, which in every part of the arch is perpendicular to the joint: But the pressure on the joint, arising from this cause, is much less than this, by reason of the friction of

Center.

the joints. A block of dry freestone will not slide down at all; and therefore will not press on the centering, if the joint be not elevated 35 degrees at least. But the archstones are not laid in this manner, by sliding them down along the joint, but are laid on the centres, and slide down *their* slope, till they touch the blocks on which they are to rest; so that, in laying the archstones, we are by no means allowed to make the great deduction from their weight just now mentioned, and which Mr Couplet prescribes (Mem. Acad. Sciences, 1729). But there is another cause which diminishes the pressure on the centres; each block slides down the planks on which it is laid, and presses on the block below it, in the direction of the tangent to the arch. This pressure is transmitted through this block, in the same direction, to the next, and through it to the third, &c. In this manner it is plain that, as the arch advances, there is a tangential pressure on the lower archstones, which diminishes their pressure on the frame, and, if sufficiently great, might even push them away from it. Mr Couplet has given an analysis of this pressure, and shews, that in a semicircular arch of uniform thickness none of the arch stones below 30° press on the frames. But he (without saying so) calculates on the supposition that the blocks descend along the circumference of this frame in the same manner as if it were perfectly smooth. As this is far from being the case, and as the obstructions are to the last degree various and irregular, it is quite useless to institute any calculation on the subject. A little reflection will convince the reader, that in this case the obstruction arising from friction *must* be taken into account, and that it *must not* be taken into account in estimating the pressure of each successive course of stones as they are laid. It is enough that we see that the pressure of the lower courses of archstones on the frame is diminished. Mr Couplet says, that the whole pressure of a semicircular arch is but $\frac{4}{5}$ ths of its weight; but it is much greater, for the reason just now given. We have tried, with a well made wooden model (of which the circumference was rubbed with black lead to render it more slippery), whether *any* part of the wooden blocks representing the archstones were detached from the frame by the tangential pressure of the superior blocks; but we could not say confidently that any were so detached. We perceived that all kept hold of a thin slip of Chinese paper (also rubbed with black lead) between them and the frame, so that a sensible force was required to pull it out. From a combination of circumstances, which would be tedious to relate, we believe that the centres carry more than two-thirds of the weight of the arch before the keystone is set. In elliptical and lower pitched circular arches, the proportion is still greater.

It seems reasonable enough, therefore, to dispose the framing in the manner proposed by Pitot, directing the main support to the upper mass of the arch, which presses most on the frame. We shall derive another advantage from this construction, which has not occurred to Mr Pitot.

There is an evident propriety in the manner in which he has distributed the supports of the upper part. The struts which carry the king post spring from those points of the stretcher where it rests on the struts below: thus the stretcher, on which all depends, bears no transverse strains. It is stretched by the strut above it, and it is

compressed in a small degree between the struts below it, at least by the outer ones. Mr Pitot proposes the straining beam GH as a lateral support to the stretcher, which may therefore be of two pieces: but although it *does* augment its strength, it does not seem necessary for it. The stretcher is abundantly carried by the strap, which may and should suspend it from the king post. The great use of the straining piece is to give a firm abutment to the inner struts, without allowing any lateral strain on the stretcher. *N. B.* Great care must be taken to make the hold sufficiently firm and extensive between the stretcher and the upper struts, so that its cohesion to resist the thrusts from these struts may be much employed.

The only imperfection that we find in this frame is the lateral strains which are brought upon the upper struts by the bridles, which certainly transmit to them part of the weight of the archstones on the curves. The space between the curves and ML should also have been trussed. Mr Pitot's form is, however, extremely stiff; and the causing the middle bridle to reach down to the stretcher, seems to secure the upper struts from all risk of bending.

This centre gives a very distinct view of the offices of all the parts, and makes therefore a proper introduction to the general subject. It is the simplest that can be in its principle, because all the essential parts are subjected to one kind of strain. The stretcher LL is the only exception, and its extension is rather a collateral circumstance than a step in the general support.

The examination of the strength of the frame is extremely easy. Mr Pitot gives it for an arch of 60 feet span, and supposes the archstones 7 feet long, which is a monstrous thickness for so small an arch; 4 feet is an abundant allowance, but we shall abide by his construction. He gives the following scantlings of the parts:

The ring or circumference consists of pieces of oak. 12 inches broad and 6 thick.

The stretcher LL is 12 inches square.

The straining piece GH is also 12 by 12.

The lower struts 10 by 8.

The king post 12 by 12.

The upper struts 10 by 6.

The bridles 20 by 8.

These dimensions are French, which is about $\frac{1}{3}$ th larger than ours, and the superficial dimensions (by which the section and the absolute strength is measured) is almost $\frac{1}{3}$ th larger than ours. The cubic foot, by which the stones are measured, exceeds ours nearly $\frac{1}{3}$ th. The pound is deficient about $\frac{1}{3}$ th. But since very nice calculation is neither easy nor necessary on this subject, it is needless to depart from the French measures, which would occasion many fractional parts and a troublesome reduction.

The arch is supposed to be built of stone which weighed 160 pounds per foot. Mr Pitot, by a computation (in which he has committed a mistake), says, that only $\frac{1}{4}$ th of this weight is carried by the frame. We believe, however, that this is nearer the truth than Mr Couplet's assumption of $\frac{2}{3}$ ths already mentioned.

Mr Pitot farther assumes, that a square inch of sound oak will carry 8640 pounds. By his language we should imagine that it will not carry much more: but this is very far below the strength of any British oak that we have tried; so far, indeed, that we rather imagine

Center.

10

The strength of this frame

By a centre of M. Pitot's.

Center.

gine that he means that this load may be laid on it with perfect security for any time. But to compensate for knots and other accidental imperfections, he assumes 7200 as the measure of its absolute force.

He computes the load on each frame to be 707520 pounds, which he reduces to $\frac{1}{4}$ ths, or 555908 pounds.

The absolute force of each of the lower struts is 576000 (at 7200 per inch), and that of the curves 518400. Mr Pitot, considering that the curves are kept from bending outwards by the arch stones which press on them, thinks that they may be considered as acting precisely as the outer struts EI. We have no objection to this supposition.

II
Computed.

With these data we may compute the load which the lower truss can safely bear by the rule delivered in the article CARPENTRY. We therefore proceed as follows:

Measure off by a scale of equal parts as, at , each 576000, and add tv 518400. Complete the parallelogram $avxs$, and draw the vertical xc , meeting the horizontal line aC in c . Make cb equal to ca . Join xb , and complete the parallelogram $axby$. It is evident that the diagonal xy will represent the load which these pieces can carry; for the line av is the united force of the curve AP and the strut IE, and as is the strength of IG. These two are equivalent to ax . xb is, in like manner, equivalent to the support on the other side, and xy is the load which will just balance the two supports ax and bx .

When xy is measured on the same scale, it will be found = 2850000 pounds. This is more than five times the load which actually lies on the frame. It is therefore vastly stronger than is necessary. Half of each of the linear dimensions would have been quite sufficient, and the struts needed only to be 5 inches by 4. Even this would have carried twice the weight, and would have borne the load really laid on it with perfect safety.

We proceed to measure the strength of the upper part. The force of each strut is 432000, and that of the curve is 518400; therefore, having drawn Mv parallel to the strut ON, make $Mv = 432000$, and $Ms = 432000 + 518400$. Complete the parallelogram $Msr v$. Draw the horizontal line rk , cutting the vertical MC in k , and make $ky = Mk$. It is plain, from what was done for the lower part, that My will measure the load which can be carried by the upper part. This will be found = 1160000. This is also greatly superior to the load; but not in so great a proportion as the other part. The chief part of the load lies on the upper part; but the chief reason of the difference is the greater obliquity of the upper struts. This shortens the diagonal My of the parallelogram of forces. Mr Pitot should have adverted to this; and instead of making the upper struts more slender than the lower, he should have made them stouter.

The strain on the stretcher LL is not calculated. It is measured by $r'k$, when My is the load actually lying on the upper part. Less than the sixth part of the cohesion of the stretcher is more than sufficient for the

horizontal thrust; and there is no difficulty of making the foot joints of the struts abundantly strong for the purpose. Center.

The reader will perceive that the computation just now given does not state the proportions of the strains actually exerted on the different pieces, but the load on the whole, on the supposition that each piece is subjected to a strain proportioned to its strength. The other calculation is much more complicated, but is not necessary here.

This centre has a very palpable defect. If the piers should yield to the load, and the feet of the centre fly out, the lower part will exert a very considerable strain on the stretcher, tending to break it across between N and L, and on the other side. HKF of the lower part is firmly bound together, and cannot change its shape, and will therefore act like a lever, turning round the point F. It will draw the strut HK away from its abutment with GH, and the stretcher will be strained across at the place between H and F, where it is bolted with the bridle. This may be resisted in some degree by an iron strap uniting ON and HK; but there will still be a want of proportional strength. Indeed, in an arch of such height (a semicircle), there is but little risk of this yielding of the piers; but it is an imperfection.

The centre (fig. 2.) is constructed on the same principle precisely for an elliptical arch (A). The calculation of its strength is nearly the same also; only the two upper struts of a side being parallel, the parallelogram $Msr v$ (of fig. 1.) is not needed, and in its stead we measure off on ON a line to represent twice its strength. This comes in place of Mr' of fig. 1.—N. B. The calculation proceeds on the supposition that the short straining piece MM makes but one firm body with the king post. Mr Pitot employed this piece (we presume) to separate the heads of the struts, that their obliquity might be lessened thereby; and this is a good thought; for when the angle formed by the struts on each side is very open, the strain on them becomes very great.

The stretcher of this frame is scarfed in the middle. Suppose this joint to yield a little, there is a danger of the lower strut ON losing its hold, and ceasing to join in the support: for when the crown sinks by the lengthening of the stretcher, the triangle ORN of fig. 2. will be more distorted than the space above it, and ON will be loosened. But this will not be the case when the sinking of the crown arises from the mere compression of the struts. Nor will it happen at all in the centre, fig. 1. On the contrary, the strut ON will abutt more firmly by the yielding of the foot of M.

The figure of this arch of Mr Pitot's consists of three arches of circles, each of 60 degrees. As it is elegant, it will not be unacceptable to the artist to have a construction for this purpose.

Make $BY = CD$, and $CZ = \frac{1}{2}CY$. Describe the semicircle $ZÆY$, and make $ZS = ZÆ$. S is the centre of the side arches, each of 60 degrees. The centre of the How to construct of such an arch.

(A) It is the middle arch of the bridge at Lille Adam, of which Mr Pitot had the direction. It is of 80 feet span; and rises 31 feet.

Center. the arch, which unites these two, is at the angle of an equilateral triangle STS.

This construction of Mr Pitot's makes a handsome oval, and very near an ellipsis, but lies a little without it. We shall add another of our own, which coincides with the ellipse in eight points, and furnishes the artist, by the way, a rule for drawing an infinite variety of ovals.

Let AB, DE (fig. 2. N^o 2.) be the axes of an ellipse, C the centre, and F, *f* the two foci. Make $Cb = CD$, and describe a circle $ADbe$ passing through the three given points A, D, and *b*. It may be demonstrated, that if from any point P of the arch AD be drawn a chord PD, and if a line PR *r* be drawn, making the angle $DPR = PDC$, and meeting the two axes in the points R and *r*, then R and *r* will be the centres of circles, which will form a quarter APD of an oval, which has AB and DE for its two axes.

We want an oval which shall coincide as much as possible with an ellipsis? The most likely method for this is to find the very point P where the ellipsis cuts the circle $ADbe$. The easiest way for the artist is to describe an arch of a circle *am*, having AB for its radius, and the remote focus *f* for its centre. Then set one foot of the compasses on any point P, and try whether the distance PF from the nearest focus F is exactly equal to its distance P*m* from that circle. Shifting the foot of the compasses from one point of the arch to another, will soon discover the point. This being found, draw PD, make the angle $DP*r* = PD*r*$, and R and *r* are the centres wanted. Then make $C*s* = CR$, and we get the centres for the other side.

The geometer will not relish this mechanical construction. He may therefore proceed as follows: Draw *Dd* parallel to AB, cutting the circle in *d*. Draw *ed*, cutting AC in N. Draw CG parallel to A*e*, and make the angle $CG*i* = AD*e*$. Bisect CN in O, and join O*i*. Make $OM, OM' = O*i*$, and draw MP, M'P perpendicular to AB. These ordinates will cut the circle $ADbe$ in the points P and P', where it is cut by the ellipse. We leave the demonstration as a geometrical exercise for the dilettante.

¹⁴ Centre for the nave of St Peter's. We said, that this centering of Mr Pitot's resembled in principle the one employed by Michael Angelo for the nave and transepts of St Peter's church at Rome. Fontana, who has preserved this, ascribes the construction of it to one of the name of San Gallo. A sketch of it is given in fig. 3. It is, however, so much superior, and so different in principle, from that employed for the cupola, that we cannot think it the invention of the same person. It is, like Pitot's, not only divisible, but really divided into two parts, of which the upper carries by much the greatest part of the load. The pieces are judiciously disposed, and every important beam is amply secured against all transverse strains. Its only fault is a great profusion of strength. The innermost polygon *agbb* is quite superfluous, because no strain can force in the struts which rest on the angles. Should the piers yield outwards, this polygon will be loose, and can do no service. Nor is the triangle *gib* of any use, if the king-post above it be strapped to the tie-beam and straining sill. Perhaps the inventor considered the king-post as a pillar, and wished to secure the tie-beam against its cross strain. This centering, however, must be allowed to be very well composed; and we expect that

Center. the well-informed reader will join us in preferring it to Mr Pitot's, both for simplicity of principle, for scientific propriety, and for strength.

There is one considerable advantage which may be derived from the actual division of the truss into two parts. If the tie-beam LI, instead of resting on the stretcher EF, had rested on a row of chocks formed like double wedges, placed above each other, head to point, the upper part of the centering might be struck independent of the lower, and this might be done gradually, beginning at the outer ends of the stretcher. By this procedure, the joints of the arch-stones will close on the haunches, and will almost relieve the lower centering, so that all can be pulled out together. Thus may the arch settle and consolidate in perfect safety, without any chance of breaking the bond of the mortar in any part; an accident which frequently happens in great arches. This procedure is peculiarly advisable for low pitched or elliptical arches. But this will be more clearly seen afterwards, when we treat of the internal movements of an arch of masonry.

This may suffice for an account of the more simple construction of trussed centres; and we proceed to such as have a much greater complication of principle. We shall take for examples some constructed by Mr Perronet, a very celebrated French architect.

¹⁵ Perronet's maxim of construction. Mr Perronet's general maxim of construction is to make the truss consist of several courses of separate trusses, independent (as he thinks) of each other, and thus to employ the joint support of them all. In this construction it is not intended to make use of one truss, or part of one truss, to support another, as in the former set, and as is practised in the roofs of St Paul's church, Covent Garden, and in Drury Lane theatre. Each truss spans over the whole distance of the piers, and would stand alone (having, however, a tottering equilibrium). It consists of a number of struts, set end to end, and forming a polygon. These trusses are so arranged, that the angles of one are in the middle of the sides of the next, as when a polygon is inscribed in a circle, and another (of the same number of sides) is circumscribed by lines which touch the circle in the angles of the inscribed polygon. By this construction the angles of the alternate trusses lie in lines pointing towards the centre of the curve. King-posts are therefore placed in this direction between the adjoining beams of the trusses. These king-posts consist of two beams, one on each side of the truss, and embrace the truss-beams between them, meeting in the middle of their thickness. The abutting beams are mortised, half into each half of the post. The other beam, which makes the base of the triangle, passes through the post, and a strong bolt is driven through the joint, and secured by a key or a nut. In this manner is the whole united; and it is expected, that when the load is laid on the uppermost truss, it will all butt together, forcing down the king-posts, and therefore pressing them on the beams of all the inferior trusses, causing them also to abutt on each other, and thus bear a share of the load. Mr Perronet does not assume the invention to himself; but says that it was invented and practised by Mr Mansard de Sagonne at the great bridge of Moulins. It is much more ancient, and is the work of the celebrated physician and architect Ferrault; as may be seen in the collection of machines and inventions of that gentleman published after

Center.

ter his death, and also in the great collection of inventions approved of by the Academy of Sciences. It is this which we propose to examine.

16
Centering
employed
for the
bridge of
Cravant,

Fig. 4. represents the centering employed for the bridge of Cravant. The arches are elliptical, of 60 feet span and 20 feet rise. The archstones are four feet thick, and weigh 176 pounds per foot. The truss-beams were from 15 to 18 feet long, and their section was 9 inches by 8. Each half of the king posts was about 7 feet long, and its section 9 inches by 8. The whole was of oak. The five trusses were $5\frac{1}{2}$ feet asunder. The whole weight of the arch was 135000 lbs. which we may call 600 tons (it is 558). This is about 112 tons for each truss. We must allow near 90 tons of this really to press the truss. A great part of this pressure is borne by the four beams which make the feet of the truss, coupled in pairs on each side. The diagonal of the parallelogram of forces drawn for these beams is, to one of the sides, in the proportion of 360 to 285. Therefore say, as 360 to 285; so is 90 to $71\frac{1}{2}$ tons, the thrust on each foot. The section of each is 144 inches. We may with the utmost safety lay three tons on every inch for ever. This amounts to 432 tons, which is more than six times the strain really pressing the foot beams in the direction of their length; nay, the upper truss alone is able to carry much more than its load. The absolute strength of its foot-beam is 216 tons. It is much more advantageously placed; for the diagonal of the parallelogram of forces corresponding to its position is to the side as 438 to 285. This gives $58\frac{6}{8}$ tons for the strain on each foot; which is not much above the fourth part of what it is able to carry for ever. No doubt can therefore be entertained of the superabundant strength of this centering. We see that the upper row of struts is quite sufficient, and all that is wanted is to procure stiffness for it; for it must be carefully kept in mind, that this upper row is not like an equilibrated arch. It will be very unequally loaded as the work advances. The haunches of the frame will be pressed down, and the joints at the crown raised up. This must be resisted.

Here then we may gather, by the way, a useful lesson. Let the outer row of struts be appropriated to the carriage of the load, and let the rest be employed for giving stiffness. For this purpose let the outer row have abundant strength. The advantages of this method are considerable. The position of the beams of the exterior row is more advantageous, when (as in this example) the whole is made to rest on a narrow foot: for this obliges us to make the last angle, at least of the lower row, more open, which increases the strain on the strut; besides, it is next to impossible to distribute the compressing thrusts among the different rows of the truss beams; and a beam which, during one period of the mason work, is acting the part of a strut, in another period is bearing no strain but its own weight, and in another it is stretched as a tie. A third advantage is, that, in a case like this, where all rests on a narrow foot, and the lower row of beams are bearing a great part of the thrust, the horizontal thrust on the pier is very great, and may push it aside. This is the most ruinous accident that can happen. An inch or two of yielding will cause the crown of the arch to sink prodigiously, and will instantly derange all the bearings of the abutting beams: but when the lower beams already act as ties,

and are quite adequate to their office, we render the frame perfectly stiff or unchangeable in its form, and take away the horizontal thrust from the piers *entirely*. This advantage is the more valuable, because the very circumstance which obliges us to rest all on a narrow foot, places this foot on the very top of the pier, and makes the horizontal thrust the more dangerous.

But, to proceed in our examination of the centering of Cravant bridge, let us suppose that the king posts are removed, and that the beams are joined by compass joints. If the pier shall yield in the smallest degree, both rows of struts must sink; and since the angles (at least the outermost) of the lower row are more open than those of the upper row, the crown of the lower row will sink more than that of the upper.

The angles of the alternate rows must therefore separate a little. Now restore the king posts; they prevent this separation. Therefore *they are stretched*; therefore the beams of the lower row are also stretched; consequently they no longer butt on their mortises, and must be held in their places by bolts. Thus it appears that, in this kind of sagging, the original distribution of the load among the different rows of beams is changed, and the upper row becomes loaded beyond our expectation.

If the sagging of the whole truss proceed only from the compression of the timbers, the case is different, and we may preserve the original distribution of mutual abutment more accurately. But in this case the stiffness of the frame arises chiefly from cross strains. Suppose that the frame is loaded with archstones on each side up to the posts HC, *bc*; the angles E and *e* are pressed down, and the beams EOF, *eo F* push up the point F. This cannot rise without bending the beams EOF, *eo F*; because O and *o* are held down by the double king posts, which grasp the beams between them. There is therefore a cross strain on the beams. Observe also, that the triangle EHF does not preserve its shape by the connection of its joints; for although the strut beams are mortised into the king post, they are in very shallow mortises, rather for steadying them than for holding them together. Mr Perronet did not even pin them, thinking that their abutment was very great. The triangle is kept in shape by the base EF, which is firmly bolted into the middle post at O. Had these interfections not been strongly bolted, we imagine that the centres of some of Mr Perronet's bridges would have yielded much more than they did; yet some of them yielded to a degree that our artists would have thought very dangerous. Mr Perronet was obliged to load the crown of the centering with very great weights, increasing them as the work advanced, to prevent the frames from going out of shape: in one arch of 120 feet he laid on 45 tons. Notwithstanding this imperfection, which is perhaps unavoidable, this mode of framing is undoubtedly very judicious, and perhaps the best which can be employed without depending on iron-work.

Fig. 5. represents another, constructed by Perronet For the bridge of Nogent, for an arch of 90 feet span and 28 feet rise. The trusses were 7 feet apart, and the arch was $4\frac{1}{2}$ thick; so that the unreduced load on each frame was very nearly 235 tons. The scantling of the struts was 15 by 12 inches. The principle is the same as that of the former. The chief difference is, that in this centre the outer truss-beam of the lower row is not coupled with the middle

Center.

Center.

row, but kept nearly parallel to the outer beam of the upper row. This adds greatly to the strength of the foot, and takes off much of the horizontal thrust from the pier.

Mr Perronet has shewn great judgment in causing the polygon of the inner row of truss beams gradually to approach the polygon of the outer row. By this disposition, the angles of the inner polygon are more acute than those of the outer. A little attention will shew, that the general fagging of all the polygons will keep the abutments of the lower one nearer, or exactly, to their original quantity. We must indeed except the foot beam. It is still too oblique; and, instead of converging to the foot of the upper row, it should have diverged from it. Had this been done, this centre is almost perfect in its kind. As it is, it is at least six times stronger than was absolutely necessary. We shall have occasion to refer to this figure on another occasion.

18
St Max-
ence,

This maxim is better exemplified by Mr Perronet in the centering of the bridge of St Maxence, exhibited in fig. 5. n^o 2. than in that of Nogent, fig. 5. n^o 1. But we think that a horizontal truss-beam *ab* should have been inserted (in a subordinate manner) between the king-posts next the crown on each side. This would prevent the crown from rising while the haunches only are loaded, without impairing the fine abutments of *cd*, *cd*, when the arch is nearly completed. This is an excellent centering; but is not likely to be of much use in these kingdoms; because the arch itself will be considered as ungraceful and ugly, looking like a huge lintel. Perronet says, that he preferred it to the ellipse, because it was lighter on the piers, which were thin. But the failure of one arch must be immediately followed by the ruin of all. We know much better methods of lightening the piers.

19
Neuilly,
and

Fig. 6. represents the centering of the bridge of Neuilly, near Paris, also by Perronet. The arch has 120 feet span, and 30 feet rise, and is 5 feet thick. The frames are 6 feet apart, and each carries an absolute (that is, not reduced to $\frac{1}{4}$ or to $\frac{1}{5}$) load of 350 tons. The strut beams are 17 by 14 inches in scantling. The king posts are of 15 by 9 each half; and the horizontal bridles, which bind the different frames together in five places, are also 15 by 9 each half. There are eight other horizontal binders of 9 inches square.

This is one of the most remarkable arches in the world; not altogether on account of its width (for there are several much wider), but for the flatness at the crown; for about 26 feet on each side of the middle it was intended to be a portion of a circle of 150 feet radius. An arch (semicircular) of 300 feet span might therefore be easily constructed, and would be much stronger than this, because its horizontal thrust at the crown would be vastly greater, and would keep it more firmly united.

The bolts of this centre are differently placed from those of the former; and the change is judicious. Mr Perronet had doubtless found by this time, that the stiffness of his framing depended on the transverse strength of the beams; and therefore he was careful not to weaken them by the bolts. But notwithstanding all his care, the framing sunk upwards of 13 inches before the key-stones were laid; and during the progress of the work, the crown rose and sunk, by various steps, as the loading

was extended along it. When 20 courses were laid on each side, and about 16 tons laid on the crown of each frame, it sunk about an inch. When 46 courses were laid, and the crown loaded with 50 tons, it sunk about half an inch more. It continued sinking as the work advanced; and when the keystone was set it had sunk $13\frac{1}{4}$ inches. But this sinking was not general; on the contrary, the frame had risen greatly at the very haunches, so as to open the upper part of the joints, many of which gaped an inch; and this opening of the joints gradually extended from the haunches towards the crown, in the neighbourhood of which they opened on the under side. This evidently arose from a want of stiffness in the frame. But these joints closed again when the centres were struck, as will be mentioned afterwards.

We have taken particular notice of the movements and twisting of this centre, because we think that they indicate a deficiency, not only of stiffness, but of abutment among the truss beams. The whole has been too flexible, because the angles are too obtuse: This arises from their multiplicity. When the intercepted arches have so little curvature, the power of the load to press it inward increases very fast. When the intercepted arch is reduced to one half, this power is more than doubled; and it is also doubled when the radius of curvature is doubled. The king-posts should have been farther apart near the crown, so that the quantity of arch between them should compensate for its diminished curvature.

The power of withstanding any given inequality of load would therefore have been greater, had the centre consisted of fewer pieces, and their angles of meeting been proportionally more acute. The greatest improvement would have been, to place the foot of the lower tier of truss-beams on the very foot of the pier, and to have also separated it at the head from the rest with a longer king-post, and thus to have made the distances of the beams on the king-posts increase gradually from the crown to the spring. This would have made all the angles of abutment more acute, and would have produced a greater pressure on all the lower tiers when the frame sagged.

Fig. 7. represents the centering of the bridge of Orleans. The arch has 100 feet span, and rises 30, and the arch-stones are 6 feet long. It is the construction of Mr Hupeau, the first architect of the bridge. It is the boldest work of the kind that we have seen, and is constructed on clear principles. The main abutments are few in number. Because the beams of the outer polygon are long, they are very well supported by straining beams in the middle; and the struts or braces which support and butt on them, are made to rest on points carried entirely by ties. The inventor, however, seems to have thought that the angles of the inner polygon were supported by mutual compression, as in the outer polygon. But it is plain that the whole inner polygon may be formed of iron rods. Not but that both polygons may be in a state of compression (this is very possible); but the smallest sagging of the frame will change the proportions of the pressures at the angles of the two polygons. The pressures on the exterior angles will increase, and those on the lower or interior angles will diminish most rapidly; so that the abutments in the lower polygon will be next to nothing.

Center.

20
Orleans.

Center.

thing. Such points could bear very little pressure from the braces which support the middle of the long bearings of the upper beams, and their pressures must be borne chiefly by the joints supported by the king-posts. The king-posts would then be in a state of extension. It is difficult, however, to decide what is the precise state of the pressure at these interior angles.

21
Instructive
history of
this centre.

The history of the erection of this bridge will throw much light on this point, and is very instructive. Mr Hupeau died before any of the arches were carried farther than a very few of the first courses. Mr Perronet succeeded to the charge, and finished the bridge. As the work advanced, the crown of the frame rose very much. It was loaded; and it sunk as remarkably. This shewed that the lower polygon was giving very little aid. Mr Perronet then thought the frame too weak, and inserted the long beam DE, making the diagonal of the quadrangle, and very nearly in the direction of the lower beam *ab*, but falling rather below this line. He now found the frame abundantly strong. It is evident that the truss is now changed exceedingly, and consists of only the two long sides, and the short straining beam lying horizontally between their heads. The whole centering consists now of one great truss *a E e b*, and its long sides *a E*, *e b*, are trussed up at B and *f*. Had this simple idea been made the principle of the construction, it would have been excellent. The angle *a DE* might have been about 176° , and the polygon *D c b g* employed only for giving a slight support to this great angle, so as not to allow it to exceed 180° . But Mr Perronet found, that the joint *c*, at the foot of the post *E c*, was about to *draw loose*, and he was obliged to bolt long pieces of timber on each side of the joint, embracing both beams. These were evidently acting the same part as iron straps would have done; a complete proof that, whatever may have been the original pressures; there was no abutment now at the point *c*, and that the beams that met there were not in a state of compression, but were on the stretch. Mr Perronet says that he put these cheeks to the joints to *stiffen* them. But this was not their office; because the adjoining beams were not struts, but ties, as we have now proved.

We may therefore conclude, that the outer polygon, with the assistance of the pieces *ab*, DE, were carrying the whole load. We do not know the distance between the frames; but supposing them seven feet apart, and the arch 6 feet thick, and weighing 170 pounds per foot, we learn the load. The beams were 16 inches square. If we now calculate what they would bear at the same very moderate rate allowed to the other centres, we find that the beams AB and *ab* are not loaded to one-sixth of their strength.

We have given this centre as a fine example of what carpentry is able to perform, and because, by its simplicity, it is a sort of text on which the intelligent artist may make many comments. We may see plainly that, if the lower polygon had been formed of iron rods, firmly bolted into the feet of the king-posts, it would have maintained its shape completely. The service done by the beam DE was not so much an increase of abutment as a discharge of the weight and of the *pull* at the joint *c*. Therefore, in cases where the feet of the truss are *necessarily* confined to a very narrow space, we should be careful to make the upper polygon sufficient to carry

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the whole load (say by doubling its beams), and we may then make the lower polygon of slender dimensions, provided we secure the joints on the king-posts by iron straps which embrace a considerable portion of the tie on each side of the joint.

Center.

We are far from thinking that these centres are of the best kind that could be employed in their situation; but they are excellent in their kind: and a careful study of them will teach the artist much of his profession. When we have a clear conception of the state of strain in which the parts of a frame really are, we know what should be done in order to draw all the advantage possible from our materials. We have said in another place, that where we can give our joints sufficient connection (as by straps and bolts, or by cheeks or fishes), it is better to use ties than struts, because ties never bend.

We do not approve of Mr Perronet's practice of giving his trusses such narrow feet. By bringing the foot of the lower polygon farther down, we greatly diminish all the strains, and throw more load on the lower polygon: and we do not see any of Mr Perronet's centres where this might not have been done. He seems to affect a great span, to shew the wonders of his art; but our object is to teach how to make the best centre of a given quantity of materials; and how to make the most perfect centre, when we are not limited in this respect, nor in the extent of our fixed points.

We shall conclude this series of examples with one where no such affectation takes place. This is the centering of the bridge at Blackfriars, London. The span of the arch is 100 feet, and its height from the spring is about 43. The drawing fig. 8. is sufficiently minute to convey a distinct notion of the whole construction.

We need not be very particular in our observations, after what has been said on the general principles of construction. The leading maxim, in the present example, seems to be, *that every part of the arch shall be supported by a simple truss of two legs resting, one on each pier.* H, H, &c. are called APRON PIECES, to strengthen the exterior joints and to make the RING as stiff in itself as possible. From the ends of this apron-piece proceed the two legs of each truss. These legs are 12 inches square: They are not of an entire piece, but of several, meeting in firm abutment. Some of their meetings are secured by the double king-posts, which grasp them firmly between them, and are held together by bolts. At other intersections, the beams appear halved into each other; a practice which cannot but weaken them much, and would endanger their breaking by cross strains, if it were possible for the frame to change its shape. But the great breadth of this frame is an effectual stop to any such change. The fact was, that *no sinking or twisting whatever* was observed during the progress of the mason work. Three points in a straight line were marked on purpose for this observation, and were observed every day. The arch was more than six feet thick; and yet the sinking of the crown, before setting the key-stones, did not amount to one inch.

The centre employs about one-third more timber than Perronet's great centre in proportion to the span of the arch; but the circumference increases in a greater proportion than this, because it is more elevated. In every way of making a comparison of the dimensions, Mr Mylne's arch employs more timber; but

C c

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Center.

it is *beyond all comparison* stronger. The great elevation is partly the reason of this. But the disposition of the timbers is also much more advantageous, and may be copied even in the low pitched arches of Neuilly. The simple truss, reaching from pier to pier for the middle point of the arch, gives the strong support where it is most of all wanted; and in the lateral points H, although one leg of the truss is very oblique, the other compensates for it by its upright position.

The chief peculiarity of this centre is to be seen in its base. This demands a more particular attention: but we must first make some observations on the condition of an arch, as it rests on the centering after the keystones are all set, and on the gradual transference of the pressure from the boards of the centering to the joints of the archstones.

While all the archstones lie on the centering, the lower courses are also leaning pretty strongly on each other. But the mortar is hardly compressed in the joints; and least of all in the joints near the crown. Suppose the arch to be catenarian, or of any other shape that is perfectly equilibrated: When the centering is gradually withdrawn, all the archstones follow it. Their wedge-like form makes this impossible, without the middle ones squeezing the lateral ones aside. This compresses the mortar between them. As the stones thus come nearer to each other, those near the crown must descend more than those near the haunches, before every stone has lessened its distance from the next by the same quantity; for example, by the hundredth part of an inch. This circumstance alone must cause a sinking in the crown, and a change of shape. But the joints near the crown are *already* more open than those near the haunches. This produces a still greater change of form before all is settled. Some masons endeavour to remedy, or at least to diminish, this, by using no mortar in the joints near the crown. They lay the stones dry, and even force them together by wedges and blocks laid between the stones on opposite sides of the crown: They afterwards pour in fine cement. This appears a good practice. Perronet rejects it, because the wedging sometimes breaks the stones. We should not think this any great harm; because the fracture will make them close where they would otherwise lie hollow. But, after all our care, there is still a sinking of the crown of the arch. By gradually withdrawing the centering, the joints close, the archstones begin to butt on each other, and to force aside the lateral courses. This abutment gradually increasing, the pressure on the haunches of the centering is gradually diminished by the mutual abutment, and ceases entirely in that course, which is the lowest that formerly pressed it: it then ceases in the course above, and then in the third, and so on. And, in this manner, not only the centering quits the arch, gradually, from the bottom to the top, *by its own retiring from it*, but the arch also quits the centering *by changing its shape*. If the centering were now pushed up again, it would touch the arch first at the crown; and it must *lift up* that part gradually before it come again in contact with the haunches. It is evident, therefore, that an arch, built on a centre of a shape perfectly suited to equilibration, will not be in equilibrio when the centering is removed. It is therefore necessary to form the centering in such a manner (by raising the crown), that it shall *leave* the arch of

a proper form. This is a very delicate task, requiring a previous knowledge of the ensuing change of form. This cannot be ascertained by the help of any theory we are acquainted with.

But, suppose this attained, there is another difficulty: While the work advances, the centering is warped by the load laid on it, and continually increasing on each side. The first pressure on the centering forces down the haunches, and raises the crown. The arch is therefore less curved at the haunches than is intended: the joints, however, accommodate themselves to this form, and are close, and filled with mortar. When the masons approach the middle of the arch, the frame sinks there, and rises up at the haunches. This opens all the joints in that place on the *upper* side. By the time that the keystones are set, this warping has gone farther; and joints are opened on the *under* side near the crown. It is true we are here speaking rather of an extreme case, when the centering is *very* flexible; but this occurred to Mr Perronet in the two great bridges of Neuilly and of Mantz. In this last one, the crown sunk above a foot before the key was set, and the joints at the haunches opened above an inch *above*, while some nearer the crown opened near a quarter of an inch *below*.

In this condition of things, it is a delicate business to strike the centering. Were it removed in an instant, all would probably come down; for the archstones are not yet abutting on each other, and the joints in the middle are open below. Mr Perronet's method appears to us to be very judicious. He began to detach the centering at the very bottom, on each side equally, where the pressure on the centering is very slight. He cut away the blocks which were immediately under each archstone. He proceeded gradually upwards in this way with some speed, till all was detached that had been put out of shape by the bending of the centering. This being no longer supported, sunk inward, till it was stopped by the abutment which it found on the archstones near the crown, which were still resting on their blocks. During part of this process, the open joints opened still more, and looked alarming. This was owing to the removal of the load from the haunches of the centering. This allowed the crown to sink still more, by forcing out the arch stones at the haunches. He now paused some days; and during this time the two haunches, now hanging in the air, gradually pressed in toward the centering, their outer joints closing in the meanwhile. The haunches were now pressing pretty hard on the archstones nearer the crown. He then proceeded more slowly, destroying the blocks and bridgings of these upper archstones. As soon as he destroyed the support of one, it immediately yielded to the pressure of the haunch; and if the joint between it and the one adjoining toward the crown happened to be open, whether on the under or the upper side, it immediately closed on it. But in proceeding thus, he found every stone sink a little while it closed on its neighbour; and this was like to produce a ragged soffit, which is a deformity. He therefore did not allow them to sink so much. In the places of the blocks and bridgings which he had cut away, he set small billets, standing on their ends, between the centering and the archstones. These allowed the pendulous arch to push toward the crown without sensibly descending; for the billets were pushed out of the perpendicular, and some of them tumbled down. Proceeding

Center.

24
Observations on the state of an arch as it rests on the centering.

25
A delicate business to strike the centering.

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Center,

ing in this way, he advanced to the very next course to the keystone on each side, the joints closing all the way as he advanced. The last job was very troublesome; we mean the detaching the three uppermost courses from the centering: for the whole elasticity of the centering was now trying to unbend, and pressing hard against them. He found that they were lifted up; for the joints beyond them, which had closed completely, now opened again below; but this job was finished in one day, and the centre sprung up two or three inches, and the whole arch sunk about six inches. This was an anxious time; for he dreaded the great momentum of such a vast mass of matter. It was hard to say where it would stop. He had the pleasure to see that it stopped very soon, settling slowly as the mortar was compressed, and after one or two days settling no more. This settling was very considerable both in the bridge at Neuilly and in that at Mantz. In the former, the sinking during the work amounted to 13 inches. It sunk six inches more when the blocks and bridgings were taken out, and $1\frac{1}{2}$ when the little standards were destroyed, and $1\frac{1}{2}$ more next day; so that the whole sinking of the *pendulous* arch was $9\frac{1}{2}$ inches, besides what it had sunk by the bending and compression of the centering.

The crown of the centering was an arch of a circle described with a radius of 150 feet; but by the sinking of the arch its shape was considerably changed, and about 60 feet of it formed an arch of a circle whose radius was 244 feet. Hence Mr Perronet infers, that a semicircle of 500 feet span may be erected. It would no doubt be stronger than this arch, because its greater horizontal thrust would keep the stones firmer together. The sinking of the arches at Mantz was not quite so great, but every thing proceeded in the same way. It amounted in all to $20\frac{1}{2}$ inches, of which 12 inches were owing to the compression and bending of the centering.

In fig. 5. n^o 1. may be observed an indication of this procedure of the masonry. There may be noticed a horizontal line *ac*, and a diagonal *ab*. These are supposed to be drawn on the masonry as it would have stood had the frames not yielded during the building. The dotted line *Ab'c'* shews the shape which it took by the sinking of the centering. The dotted line on the other side was actually drawn on the masonry when the keystone was set; and the wavy black line on the same side shews the form which the dotted line took by the striking of the centering. The undulated part of this line cuts its former position a little below the middle, going without it below, and falling within it above. This shews very distinctly the movement of the whole masonry, distinguishing the parts that were forced out and the parts which sunk inward.

We presume that the practical reader will think this account of the internal movements of a stupendous arch very instructive and useful. As Mr Perronet observed it to be uniformly the same in several very large arches which he erected, we may conclude that it is the general process of nature. We by no means have the confidence in the durability or solidity of his arches which he prudently professes to have. We have conversed with some very experienced masons, who have also erected very great arches, and in very difficult situations, which have given universal satisfaction; and we have found

them uniformly of opinion, that an arch which has settled to such a proportion of its curvature as to change the radius from 150 to 244 feet, is in a very hazardous situation. They think the hazard the greater, because the span of the arch is so great in proportion to its weight (as they express it very emphatically) or its height. The weight, say they, of the haunches is too small for forcing together the keystones, which have scarcely any wedge-like form to keep them from sliding down. This is very good reasoning, and expresses very familiar notions. The mechanic would say, that the horizontal thrust at the crown is too small. When we questioned them about the propriety of Mr Perronet's method of removing the centering, they unanimously approved of its general principle, but said that it was very ticklish indeed in the execution. The cases which he narrates were new to them. They should have almost despaired of success with arches which had gone so much out of shape by the bending of the centres; because, said they, the slope of the centering, to a great distance from the crown, was so little, that the archstones could not slide outwards along it, to close even the under side of the joints which had opened above the haunches; so that *all* the archstones were at too great a distance from each other; and a great *general* subsiding of the whole was necessary for bringing them even to touch each other. They had *never* observed such bendings of the centerings which they had employed, having never allowed themselves to contract the feet of their trusses into such narrow spaces. They observed, that nothing but lighters with their masts down can pass under the trusses, and that the sides must be so protected by advanced works from the accidental shock of a loaded boat, that there cannot be left room for more than one. They added, that the bridges of communication, necessary for the expeditious conducting of the work, made all this supposed roominess useless: besides, the business can hardly be so urgent and crowded anywhere, as to make the passage through every arch indispensably necessary. Nor was the inconvenience of this obstruction greatly complained of during the erection of Westminster or Blackfriars bridges. Nothing should come in competition with the *undoubted* solidity of the centering and the future arch; and all boasting display of talent and ingenuity by an engineer, in the exhibition of the wonders of his art, is misplaced here.

These appeared to us good reasons for preferring the more cautious, and incomparably more secure, construction of Mr Mylne, in which the breadth given to each base of the trusses permitted a much more effective disposition of the abutting timbers, and also enabled the engineer to make it incomparably stiffer; so that no change need be apprehended in the joints which have already closed, and in which the mortar has already taken its set, and commenced an union that never can be restored if it be once broken in the smallest degree, no not even by greater compression.

Here we beg leave to mention our notions of the connection that is formed by mortar composed of lime or gypsum. We consider it as consisting chiefly, if not solely, in a crystallization of the lime or gypsum and water. As much water is taken up as is necessary for the formation of the crystals during their gradual conversion into mild calcareous earth or alabaster, and the rest evaporates. When the free access of air is abso-

26

The foregoing observations exemplified.

Center

27
The connection that is formed by mortar of lime, &c.

Center. lutely prevented, the crystallization never proceeds to that state, even although the mortar becomes extremely dry and hard. We had an opportunity of observing this accidentally, when passing through Maestricht in 1770, while they were cutting up a massy revetment of a part of the fortifications more than 300 years old. The mortar between the bricks was harder than the bricks (which were Dutch clinkers, such as are now used only for the greatest loads); but when mixed with water it made it lime water, seemingly as strong as if fresh lime had been used. We observed the same thing in one small part of a huge mass of ancient Roman work near Romney in Kent; but the rest, and all the *very old* mortar that we have seen, was in a mild state, and was generally much harder than what produced any lime-water. Now when the mortar in the joints has begun its first crystallization, and is allowed to remain in perfect rest, we are confident that the subsequent crystals, whether of lime, or of calcareous earth, or of gypsum, will be much larger and stronger than can ever be produced if they are once broken; and the farther that this crystallization has been carried, that is, the harder that the mortar has become, less of it remains to take any new crystallization. Why should it be otherwise here than in every other crystallization that we are acquainted with?

28 Necessity of keeping the joints in their first state. We think therefore that it is of great consequence to keep the joints in their *first* state if possible; and that the strength (as far as it depends on the mortar) is greatly diminished by their opening; especially when the mortar has acquired considerable hardness, which it will do in a month or six weeks, if it be good. The cohesion given by mortar is indeed a mere trifle, when opposed to a force which tends to open the joints, acting, as it generally does, with the transverse force of a lever: but in situations where the overload on any particular archstones tends to push them down through between their neighbours, like wedges, the cohesion of the mortar is then of very great consequence.

We must make another observation. Mr Perronet's ingenious process tended very effectually to close the joints. It doing this, the forces which he brought into action had little to oppose them; but as soon as they were closed, the contact of the parts formerly open opposed an obstruction incomparably greater, and immediately balanced a force which was but just able to turn the stone gently about the two edges in which it touched the adjoining stones. This is an important remark, though seemingly very trifling; and we wish the practitioner to have a very clear conception of it; but it would take a multitude of words to explain it. It is worth an experiment. Form a little arch of wooden blocks; and form one of these so, that when they are all resting on the centering, it may be open at the outer joint—Remove the centering—Then press on the arch at some distance from the open joint.—You will find that a very small pressure will make the arch bend till that joint closes.—Press a little harder, and the arch will bend more, and the next joint will open.—Thus you will find that, by pressing alternately on each side of the open joint, that stone can easily be made to flap over to either side; and that immediately after this is done the resistance increases greatly. This shews clearly, that a very moderate force, judiciously employed, will close the joints, but will not press the parts strongly toge-

ther. The joints therefore are *closed*, but *no more than closed*, and are hanging only by the edges by which they were hanging while the joints were open. The arch, therefore, though apparently close and firm, is but loose and tottering. Mr Perronet says, that his arches were firm, because hardly a stone was observed to chip or splinter off at the edges by the settlement. But he had done every thing to prevent this, by digging out the mortar from between the headers, to the depth of two inches, with saws made on purpose. But we are well informed, that before the year 1791 (twenty years after the erection) the arches at Neuilly had sunk very sensibly, and that very large splinters had flown off in several places. It could not be otherwise. The original construction was too bold; we may say needlessly and ostentatiously bold. A very gentle slope of the roadway, which would not have slackened the mad gallop of a ducal carriage, nor sensibly checked the laborious pull of a loaded waggon, and a proper difference in the size of the arches, would have made this wonderful bridge incomparably stronger and also much more elegant and pleasing to the eye. Indeed, it is far from being as handsome as it might have been. The ellipse is a most pleasing figure to every beholder; but this is concealed as much as possible, and it is attempted to give the whole the appearance of a tremendous lintel. It has the oppressive look of danger. It will not be of long duration. The bridge at Mantz is still more exceptionable, because its piers are tall and slender. If any one of the arches fails, the rest must fall in a moment. An arch of Blackfriars Bridge might be blown up without disturbing its neighbours.

Mr Perronet mentions another mode of striking the A bad method of striking the center. centering, which he says is very usual in France. Every second bridging is cut out. Some time after, every second of the remainder; after this, every second of the remainder; and so on, till all are removed. This is never practised in this country, and is certainly a very bad method. It leaves the arch hanging by a number of distant points; and it is wonderful that any arch can bear this treatment.

Our architects have generally proceeded with extreme caution. Wherever they could, they supported the centering by intermediate pillars, even when it was a trussed centre, having a tie-beam reaching from side to side. The centre was made to rest, not immediately on these pillars, but on pieces of timber formed like acute wedges, placed in pairs, one above the other, and having the point of the one on the thick end of the other. These wedges were well soaped and rubbed with black lead, to make them slippery. When the centres are to be struck, men are stationed at each pair of the wedges with heavy mallets. They are directed to strike together on the opposite wedges. By this operation, the whole centering descends together; or, when any part of the arch is observed to have opened its joints on the upper side, the wedges below that part are slackened. The framing may perhaps bend a little, and allow that part to subside. If any part of the arch is observed to open its joints on the under side, the wedges below that part are allowed to stand after the rest have been slackened. By this process, the whole comes down gradually, and as slowly as we please, and the defects of every part of the arch may be attended to. Indeed the caution and moderation of our builders have commonly been such, that few

9 Mr Perronet's constructions too bold.

30 A bad method of striking the center.

31 The common method in Britain.

Center. few defects have been allowed to shew themselves. We are but little acquainted with joints opening to the extent of two inches, and in such a case would probably lift every stone of the arch again (B). We have not employed trussed centerings so much perhaps as we should have done; nor do we see their advantage (speaking as mere builders) over centres supported all over, and unchangeable in their form. Such centres must bend a little, and require loading on the middle to keep them in shape. Their compression and their elasticity, are very troublesome in the striking of the centres in Mr Perronet's manner. The elasticity is indeed of use when the centres are struck in the way now described.

These observations on the management of the internal movements of a great arch will enable the reader to appreciate all the merit of Mr Mylne's very ingenious construction. We proceed therefore to complete our description.

The gradual enlargement of the base of the piers of Blackfriars bridge enabled the architect to place a series of five posts *c, c, c, c, c*, one on each step of the pier; the ingenious contexture of which made it like one solid block of stone (see ARCH, Supplement). These struts were gradually more and more oblique, till the outer one formed an obtuse angle with the lowest side of the interior polygon of the trufs. On the top of these posts was laid a sloping SEAT or beam D of stout oak, the upper part of which was formed like a zig-zag scarfing. The posts were not perpendicular to the under side of the seat. The angles next the pier were somewhat obtuse. Short pieces of wood were placed between the heads of the posts (but not mortised into them), to prevent them from slipping back. Each face of the scarf was covered with a thick and smooth plate of copper. The feet of the trufs were mortised into a similar piece F, which may be called the SOLE of the trufs, having its lower side notched in the same manner with the upper side of D, and like it covered with copper. Between these two lay the STRIKING WEDGE E, the faces of which corresponded exactly with the slant faces of the seat and the sole. The wedge was so placed, that the corresponding faces touched each other for about half of their length. A block of wood was put in at the broad end or base of this wedge, to keep it from slipping back during the laying the arch-stones. Its outer end E was bound with iron, and had an iron bolt several inches long driven into it. The head of this bolt was broad enough to cover the whole wood of the wedge within the iron ferule.

We presume that the reader, by this time, foresees the use of this wedge. It is to be driven in between the sole and the seat (having first taken out the block at the base of the wedge). As it advances into the wider spaces, the whole trufs must descend, and be freed from the arch; but it will require prodigious blows to drive it back. Mr Mylne did not think so, founding

his expectation on what he saw in the launching of great ships, which slide very easily on a slope of 10 or 12 degrees. He rather feared, that taking out the block behind would allow the wedge to be pushed back at once, so that the descent of the trufs would be too rapid. However, to be certain of the operation, he had prepared an abundant force in a very ingenious manner. A heavy beam of oak, armed at the end with iron, was suspended from two points of the centre like a battering ram, to be used in the same manner. Nothing could be more simple in its structure, more powerful in its operation, or more easy in its management. Accordingly the success was to his wish. The wedge did not slip back of itself; and very moderate blows of the ram drove it back with the greatest ease. The whole operation was over in a very few minutes. The spectators had suspected, that the space allowed for the recess of the wedge was not sufficient for the settlement of the arch; but the architect trusted to the precautions he had taken in its construction. The reader, by turning to the article ARCH in this Supplement, will see that there was only the arch LY which could be expected to settle: accordingly, the recess of the wedge was found to be much more than was necessary. However, had this not been the case, it was only necessary to take out the pieces between the posts below the seat, and then to drive back the heads of the struts; but this was not needed (we believe) in any of the arches. We are well assured that none of the arches sunk an inch and a half. The great arch of 100 feet span did not sink one inch at the crown. It could hardly be perceived whether the arch quitted the centering gradually or not, so small had been the changes of shape.

We have no hesitation in saying, that (if we except the great³³ waste of great timber by uncommon joggling) the whole of this performance is the most perfect of any that has come to our knowledge. We doubt not but that several have equalled it, or may have excelled it; but we do not know of them: and we think that the bringing forward such performances is no less serviceable to the public, than it is honourable to the inventor. Nor do we suppose that any views of interest can be so powerful as to prevent an ingenious architect from communicating to the public such honourable specimens of his own talents. We should be happy to communicate more of this kind; for we consider it as a very important article of practical mechanics, and think that it is of consequence to the nation that it should be very generally understood. In every corner of the country bridges are to be built—we have everywhere good masons, who are fully able to execute any practicable project, but too little acquainted with principle to invent, or to accommodate even what they know to local circumstances, and are very apt to be duped by appearances of ingenuity, or misled by erroneous notions of the strains which are excited. We profess more science, and

(B) The writer of this article can only say, that, after much inquiry, he has no information of any arch being received from the builder as sufficient that had suffered half the change of shape mentioned by Mr Perronet. The arch of Dublin bridge, built by an excellent, but a very private, mason, Mr Steeven, is 105 feet wide, with only 22 feet of rise. It was erected (but not on a trussed centering) without changing one full inch in its elevation; and when the centering was removed, it sunk only $1\frac{1}{2}$ inches, and about half an inch more when the parapets were added and the bridge completely finished.

Center.

Center.

and to treat the subject with the assistance of accurate principles: But while we are certain that every circumstance is susceptible of the most accurate determination, we must acknowledge that we have by no means attained an accurate knowledge of all the strains which are produced and excited in a frame of carpentry, which is settling and changing its shape, even though it be not very complicated; far less are we possessed of a clear view of what happens in a mass of masonry in similar conditions. Therefore, though we speak with the strong belief of our being right, we speak with a sense of our fallibility, and with great deference to the judgment of eminent and experienced architects and engineers. We should consider their free and candid criticisms as the highest favour; and we even solicit them, with assurances of thanks, and that we will take some opportunity, before the close of this work, to acknowledge and correct our mistakes. We even presume to hope, that the liberal-minded artist will be pleased with this opportunity which we give him of increasing the national stock of knowledge. Let mutual jealousy and rivalry reign in the breasts, and prompt the exertions, of our restless neighbours on the continent—let them think that the dignity of man consists in perpetual warfare, in which every individual feels himself indebted only to himself, freed from all the sweet ties of domestic partiality, of friendship, and of patriotic attachment. We hope that the hearts of Britons will long continue to be warmed and fortified by the thoughts of mutual assistance, mutual co-operation, mutual attachment, and a patriotic preference of their countrymen to all other men. While these sentiments are regulated by unshaken honesty, by candour, and by Christian charity, we shall be secured from the errors of partial attachments, and yet enjoy all the pleasures of unsophisticated nature. Families will still be bound together by the affectionate ties of blood; and the whole frame of British society will be in harmony with the bonds which connect the members of each family, by their endless crossings and intermixings. In this state, the state of social nature, the man of talents will not lock up all the fruits of his exertions in his own breast, but will feel a pleasure in imparting them to a society that is dear to him, and on which he depends for all his best enjoyments. Nothing will hold the good man back when this is in his power, but the virtuous use which he can make of his superiority in the discharge of his own little circle of duties. This is all that is required of true patriotism; and it is not too much to be expected from Britons, who feel a pleasure in viewing their country as the great school of the arts, under the patronage of a sovereign who has done more for their improvement than all the other princes of Europe, and who (we are well assured) is now meditating a plan which must be highly gratifying to every eminent professor of the arts.

34
The subject of this article connected with the construction of wooden bridges.

THE subject which we have been considering is very closely connected with the construction of wooden bridges. These are not always constructed on the sole principles of equilibrium, by means of mutual abutment. They are stiff frames of carpentry, where, by a proper disposition, beams are put into a state of extension, as well as of compression, so as to stand in place of solid bodies as big as the spaces which the beams enclose; and thus we are enabled to couple two, three, or four

of these together, and set them in abutment with each other like mighty arch-stones. We shall close this article, therefore, with two or three specimens of wooden bridges, disposed in a series of progressive composition, so as to serve as a sort of introduction to the art in general, and furnish a principle which will enable the intelligent and cautious artist to push it with confidence as far as it can go.

The general problem is this. Suppose that a bridge is to be thrown over the space AB (fig. 9.), and that this is too wide for the strength of the size of timber which is at our command; how may this beam AB be supported with sufficient effect? There are but two ways in which the middle point C (where the greatest strain is) can be supported: 1. It may be suspended by two ropes, iron rods, or wooden ties, DC, EC, made fast to two firm points, D, E, above it; or it may rest on the ridge of two rafters *dC*, *eC*, which rest on two firm points *d*, *e*, below it. 2. It may be supported by connecting it with a point so supported; and this connection may be formed, either by suspending it from this point, or by a post resting on it. Thus it may hang, by means of a rod or a king-post FC, from the ridge F of two rafters AF, BF; or it may rest on the strut Cf, whose lower extremity *f* is carried by the ropes, rods, or wooden ties *Af*, *Bf*.

Plate XVII.

Whichsoever of these methods we employ, it follows, from the principles of carpentry, that the support given to the point C is so much the more powerful, as we make the angle DCE, or *dCe*, or the equivalent angles AFB, or *AfB*, more acute.

Each of these methods may be supposed equally strong. Our choice will depend chiefly on the facility of finding the proper points of support D, E, *d*, *e*; except in the second case, where we require no fixed points but A and B. The simple forms of the first case require a great extent of figure. Very rarely can we suspend it from points situated as D and E. It is even seldom that we have depth enough of bank to allow the support of the rafters *dC*, *eC*; but we can always find room for the simple truss AFB. This therefore is the most usually practised.

35
The usual and simplest method of constructing such bridges.

In the construction, we must follow the maxims and directions prescribed in the article CARPENTRY of this volume, and the article ROOF of the *Encycl.* The beams FA, FB must be mortised into AB, in the firmest manner, and there secured with straps and bolts; and the middle must hang by a strap attached to the king-post FC, or to the iron rod that is used for a king-post. No mortising in the point C must be employed; it is unnecessary, and it is hurtful, because it weakens the beam, and because it lodges water, and soon decays by rot. The best practice is not to suspend the beam immediately by this strap, but to let it rest, as in fig. 10. on a beam C, which crosses the bridge below, and has its other end supported in the same manner by the other truss.

It is evident that the length of the king-post has no effect on the support of C. We may therefore contract every thing, and preserve the same strength of support, by finding two points *a* and *b* (fig. 11.) in the banks, at a moderate distance below A and B, and setting up the rafters *aF*, *bF*, and suspending C from the shortened king-post. In this construction, when the beam AB rests on a cross bearer, as is drawn here, the struts

Center.

struts *a F*, *b F* are kept clear of it. No connection between them is necessary, and it may be hurtful, by inducing cross strains on both. It will, however, greatly increase the stiffness of the whole. This construction may safely be loaded with ten times the weight that *AB* can carry alone.

³⁶
An im-
provement
of that me-
thod.

Suppose this done, and that the scantling of *AB* is too weak for carrying the weight which may be brought on the parts *AC*, *CB*. We may now truss up each half, as in fig. 12. and then the whole will form a handsome bridge, of the simplest construction possible. The interfections of the secondary braces with those of the main truss will form a hand-rail of agreeable figure.

We are not confined to the employment of an entire piece *AB*, nor to a rectilineal form. We may frame the bridge as in fig. 13. and in this form we disuade from allowing any connection with the middle points of the main braces. This construction also may be followed till each beam *AC* and *CB* is loaded to ten times what it can safely bear without the secondary trussing.

³⁷
Another
method.

There is another way by which a bridge of one beam may be supported beyond the power of the first and simplest construction. This is represented in fig. 14. and fig. 15. The truss beam *FG* should occupy one-third of *AB*. The advantage of this construction is very considerable. The great elevation of the braces (which is a principal element of the strength) is preferred, and the braces are greatly shortened.

This method may be pushed still farther, as in fig. 16.

³⁸
These me-
thods com-
bined.

And all these methods may be combined, by joining the constructions of fig. 14. and fig. 15. with that of fig. 16.

In all of them there is much room for the display of skill, in the proper adjustment of the scantling of the timber, and the obliquity of the braces to the lengths of the different bearings. A very oblique strut, or a slender one, will suffice for a small load, and may often give an opportunity to increase the general strength; while the great timbers and upright supports are reserved for the main pressures. Nothing will improve the composition so much as reflecting progressively, and in the order of these examples, on the whole. This alone can preserve the great principle in its simplicity and full energy.

³⁹
The ele-
ments of all
that can be
done in this
art.

These constructions are the elements of all that can be done in the art of building wooden bridges, and are to be found more or less obviously and distinctly in all attempts of this kind. We may assert, that the more obviously they appear, the more perfect the bridge will be. It is astonishing to what extent the principle may be carried. We have seen a bridge of 42 feet span formed of two oak trusses, the biggest timber of which did not exceed six inches square, bearing with perfect steadiness and safety a waggon loaded with more than two tons, drawn by four stout horses. It was framed as fig. 16. nearly, with the addition of the dotted lines, and was near thirty years old; protected, however, from the weather by a wooden roof, as many bridges in Germany are.

We recollect another in the neighbourhood of Stetin, which seemed constructed with great judgment and spirit. It had a carriage road in the middle about 20 feet (we think) wide, and on each side a foot-way about

five feet wide. The span was not less than 60 feet, and the greatest scantling did not appear to exceed 10 inches by 6.

Center.

This bridge consisted of four trusses, two of which formed the outside of the bridge, and the other two made the separation between the carriage road and the two foot ways. We noticed the construction of the trusses very particularly, and found it similar to the last, except in the middle division of the upper truss, which, being very long, was double trussed, as in fig. 17.

The reader will find in that volume of Leupold's *Theatrum Machinarum*, which he calls *Theatrum Pontificum*, many specimens of wooden bridges, which are very frequent in the champain parts of Germany. They are not, in general, models of mechanic art; but the reflecting reader, who considers them *carefully*, will pick up here and there subordinate hints, which are ingenious, and may sometimes be useful.

What we have now exhibited are not to be considered as models of construction, but as elementary examples and lessons, for leading the reader systematically into a thorough conception of the subject.

We cannot quit the subject without taking notice of a wonderful bridge at Wittengen in Switzerland, slightly described by Mr Coxe (*Travels*, vol. I. 132.) It is of a construction more simple still than the bridges we have been describing. The span is 230 feet, and it rises only 25. The sketch (fig. 18.) will make it sufficiently intelligible. *ABC* is one of two great arches, approaching to a catenarian shape, built up of seven courses of solid logs of oak, in lengths of 12 or 14 feet, and 16 inches or more in thickness. These are all picked of a natural shape, suited to the intended curve; so that the wood is nowhere cut across the grain to trim it into shape. These logs are laid above each other, so that their abutting joints are alternate, like those of a brick wall; and it is indeed a wooden wall, simply built up, by laying the pieces upon each other, taking care to make the abutting joints as close as possible. They are not fastened together by pins or bolts, or by scarfings of any kind. They are, however, held together by iron straps, which surround them, at the distance of five feet from each other, where they are fastened by bolts and keys.

These two arches having been erected (by the help, we presume, of pillars, or a centering of some kind), and well butted against the rock on each side, were freed from their supports, and allowed to settle. They are so placed, that the intended road *abc* intersects them about the middle of their height. The roadway is supported by cross joists, which rest on a long horizontal summer beam. This is connected with the arches on each side by uprights bolted into them. The whole is covered with a roof, which projects over the arches on each side to defend them from the weather. Three of the spaces between these uprights have struts or braces, which give the upper work a sort of trussing in that part.

This construction is simple and artless; and appears, by the attempt to truss the ends, to be the performance of a person ignorant of principle, who has taken the whole notion from a stone arch. It is, however, of a strength much more than adequate to any load that can be laid on it. Mr Coxe says, but does not explain how, that it is so contrived that any part of it can be repaired

40

A wonder-
ful bridge
in Switzer-
land.

Center. ed independent of the rest. It was the last work of one Ulrich Grubenhann of Tuffen, in the canton of Appenzel, a carpenter without education, but celebrated for several works of the same kind; particularly the bridge over the Rhine at Schafhausen, consisting of two arches, one of 172 and the other of 193 feet span, both resting on a small rock near the middle of the river.

While writing this article, we got an account of a wooden bridge, erected in North America, in which this simple notion of Grubenhann's is mightily improved. The span of the arch was said to exceed 250 feet, and its rise exceedingly small. The description we got is very general, but sufficient, we think, to make it perfectly intelligible.

41
Another
in North
America.

In fig. 19. DD, EE, FF, are supposed to be three beams of the arch. They consist of logs of timber of small lengths, suppose of 10 or 12 feet, such as can be found of a curvature suited to its place in the arch without trimming it across the grain. Each beam is double, consisting of two logs applied to each other, side to side, and *breaking joint*, as the workmen term it. They are kept together by wedges and keys driven through them at short intervals, as at K, L, &c.

The manner of joining and strongly binding the two side pieces of each beam is shewn in fig. 20. The mortise *aicb* and *dëio*, which is cut in each half beam, is considerably longer on the outside than on the inside, where the two mortises meet. Two keys, BB and CC, are formed, each with a notch *bcd*, or *aio*, on its side; which notch fits one end of the mortise. The inner side of the key is straight, but so formed, that when both keys are in their places, they leave a space between them wider at one end than the other. A wedge AA, having the same taper as the space just mentioned, is put into it and driven hard. It is evident that this must hold the two logs firmly together.

This is a way of uniting timber not mentioned in the article CARPENTRY; and it has some peculiarities worthy of notice. In the first place, it may be employed so as to produce a very strong lateral connection, and would then co-operate finely with the other artificial methods of scarfing and tabling that we described in the article referred to. But it requires nice attention to some circumstances of construction to secure this effect. If the joints are accurately formed to each other, as if the whole had been one piece divided by an infinitely thin saw, this manner of joining will *keep* them all in their places. But no driving of the wedge AA will make them firmer, or cause one piece to press hard on the other. If the abutment of two parts of the half beam is already close, it will remain so; but if open in the smallest degree, driving of the wedge will not make it tighter. In this respect, therefore, it is not so proper as the forms described in CARPENTRY.

In order that the method now described may have the effect of *drawing* the halves of the beams together, and of keeping them hard squeezed on each other, the joints must be made so as not to correspond exactly. The prominent angle *aio* (fig. 21.), formed by the ends of the two half mortises, must be made a little more obtuse than the angle *afo* of the notch of the key which this prominence is intended to fill up. Moreover, the opposite side *et* of this key should not be quite straight, but a very little convex. With these precautions, it is easy to see that, by driving the wedge

Center. AA, we cause the notch *afo* to take hold, first at the two points *a* and *o*, and then, by continuing to drive the wedge, the sides *af*, *of*, of the notch gradually compress the wood of the half beams, and press them on each other. By continuing to drive the wedge, the mutual compression of the key and the beam squeezes all together, and the space *afoi* is completely filled up. We may see, from this process, that the mutual compression and drawing together of the timber will be greater in proportion as we make the angle *aio* more prominent, and its corresponding angle *afo* more deep; always taking care that the key shall be thick enough not to break in the narrow part.

This adjustment of the keys to the mortise is necessary on another account. Supposing the joints to fit each other exactly before driving the wedge, and that the whole shrinks a little by drying—by this the angle *aio* will become more prominent, and the angle *afo* will become more shallow; the joint will open at *a* and *o*, and the mutual compressure will be at an end.

We may also observe, that this method will not give any additional firmness to the abutments of the different lengths employed to piece out the arch-beam; in which respect it differs materially from the other modes of joining timber.

Having shewn how each beam is pieced together, we must now shew how a number of them are united, so as to compose an arch of any thickness. This is done in the very same way. The beams have other mortises worked out of their inner sides, half out of each half of the beam. The ends of the mortises are formed in the same way with those already described. Long keys BB, CC, (fig. 19.) are made to fit them properly, the notches being placed so as to keep the beams at a proper distance from each other. It is now plain that driving in a long wedge AA will bind all together.

In this manner may an arch be extended to any span, and made of any thickness of arching. The bridge over Portsmouth river in North America was more than 250 feet in length, and consisted of several parallel arches of beams. The inventor (we think that his name is Bludget) said that he found the strength so great, that he could with perfect confidence make one of four times the span.

We admire the ingenuity of this construction, and think it very effectual for bringing the timbers into firm and uniform abutment; but we imagine that it requires equilibration, because it is extremely flexible. There is nothing to keep it from bending, by an inequality of load, but the transverse strength of the beams. The keys and wedges can have very little power to prevent this bending. The distance between the beams will also contribute little or nothing to the stiffness; nay, we imagine that a great distance between them will make the frame more flexible. Could the beams be placed so near each other that they could be somehow joggled on each other, the whole would be stiffer; but at present they will bend like the plates of a coach-spring. But nothing hinders us from adding diagonal pieces to this construction, which will give it any degree of stiffness, and will enable it to bear any inequality of loading. When completed in this manner, we imagine that it will be at least equal to any construction that has yet been thought of. One advantage it possesses that is very precious: Any piece that fails
may

Fig. 3.



Fig. 2. N^o 2.

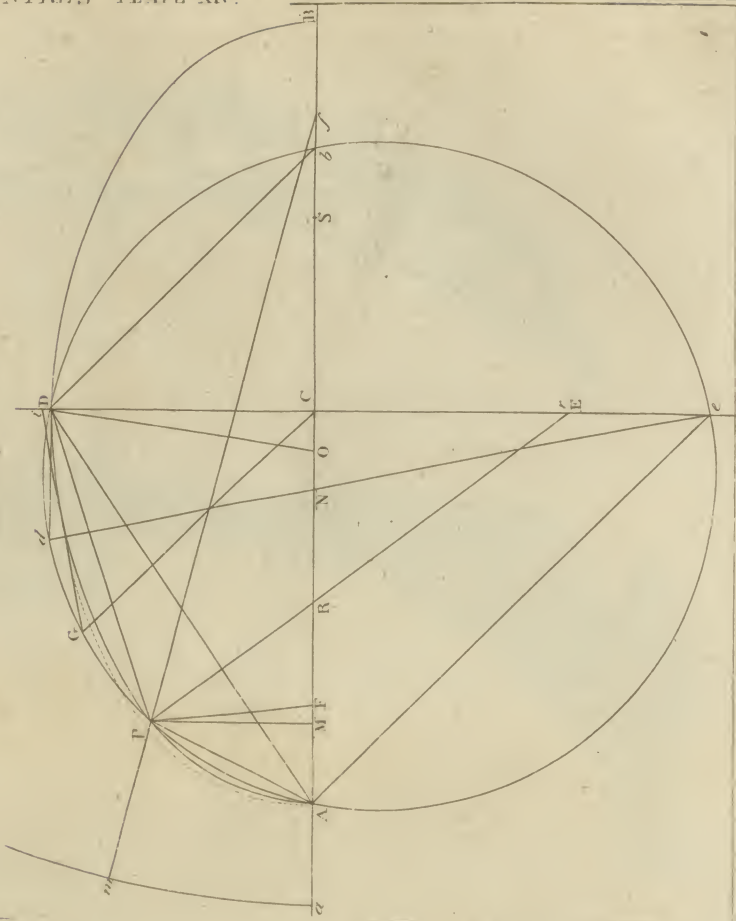


Fig. 1.

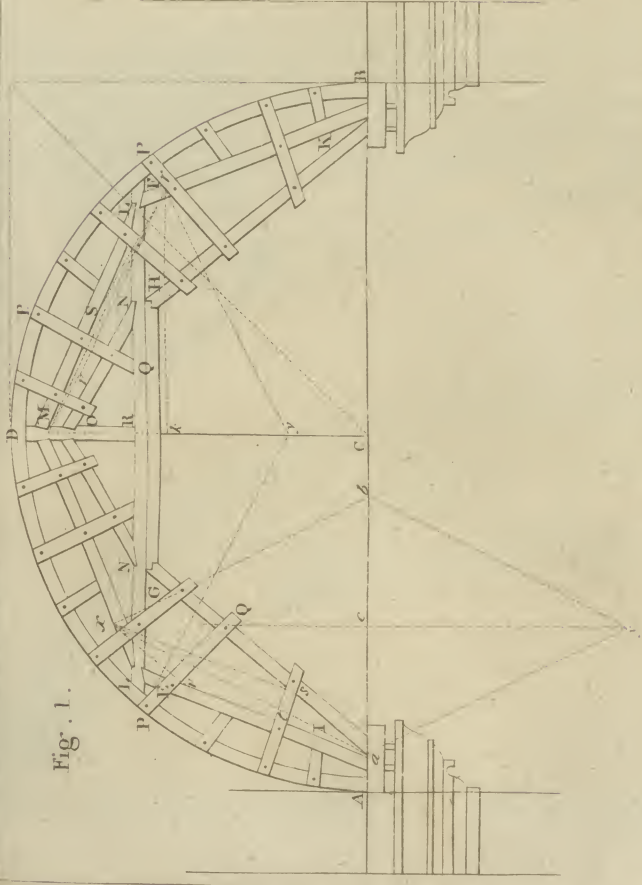
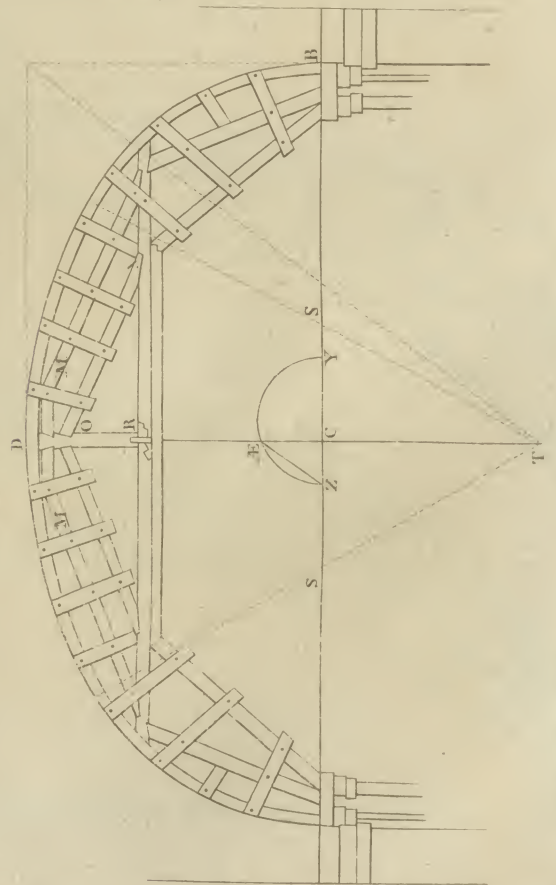


Fig. 2.



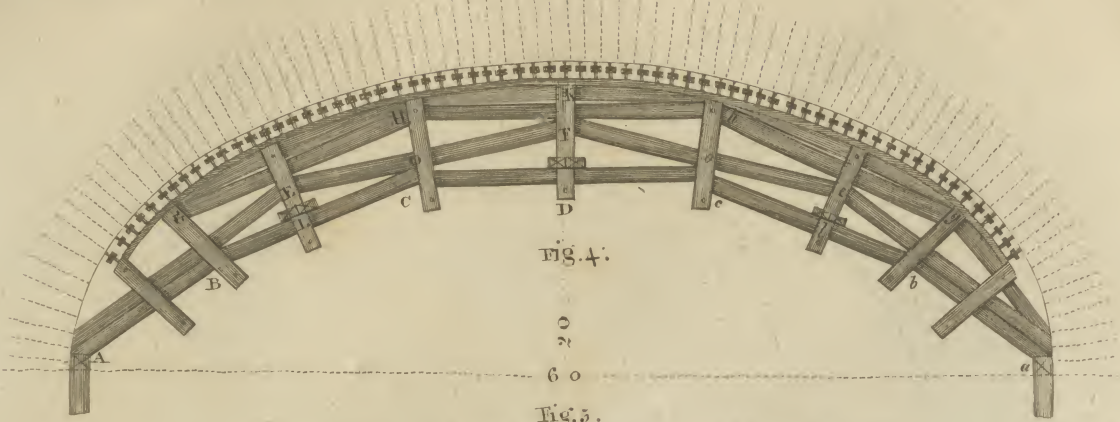


Fig. 4.

0

2

60

Fig. 5.



Fig. 5. N° 2.

80

90

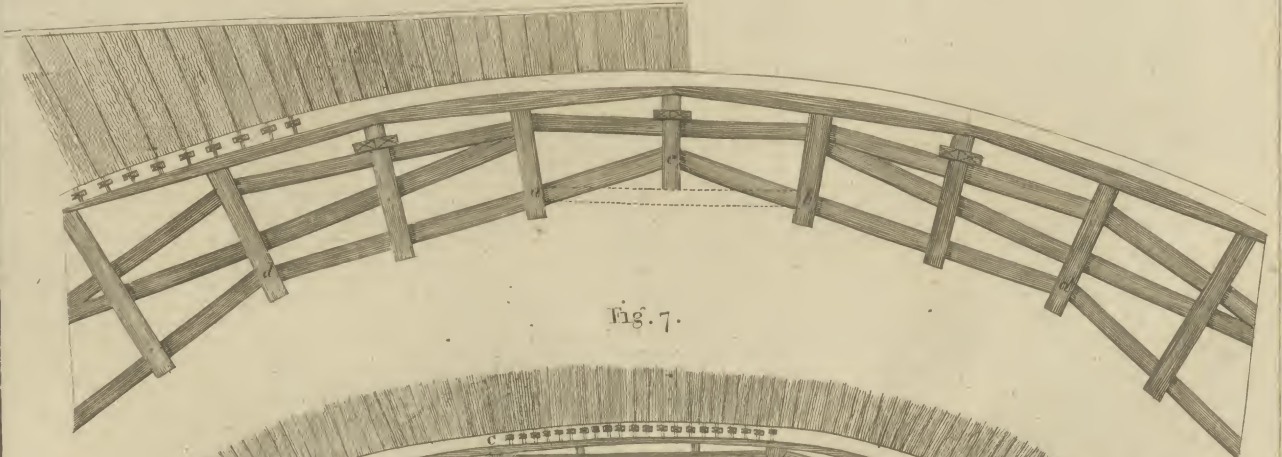
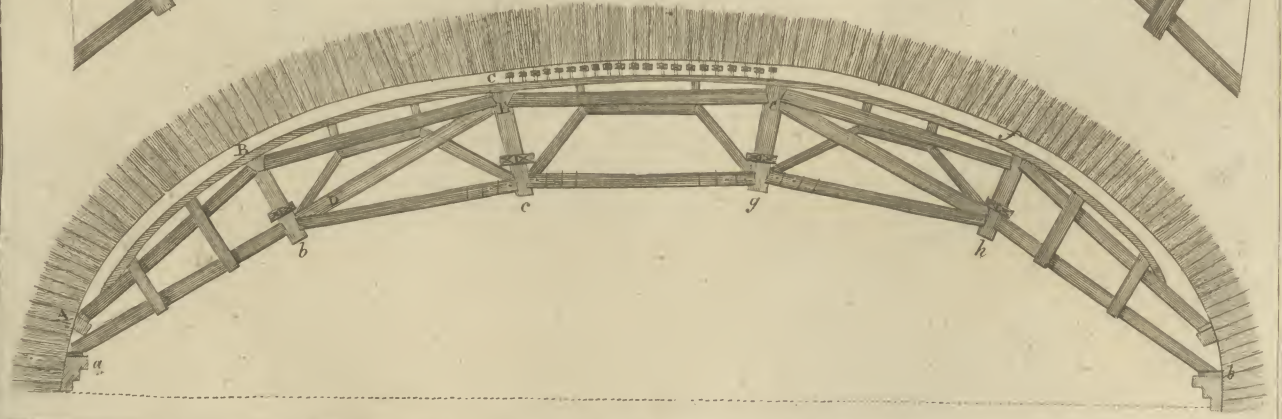
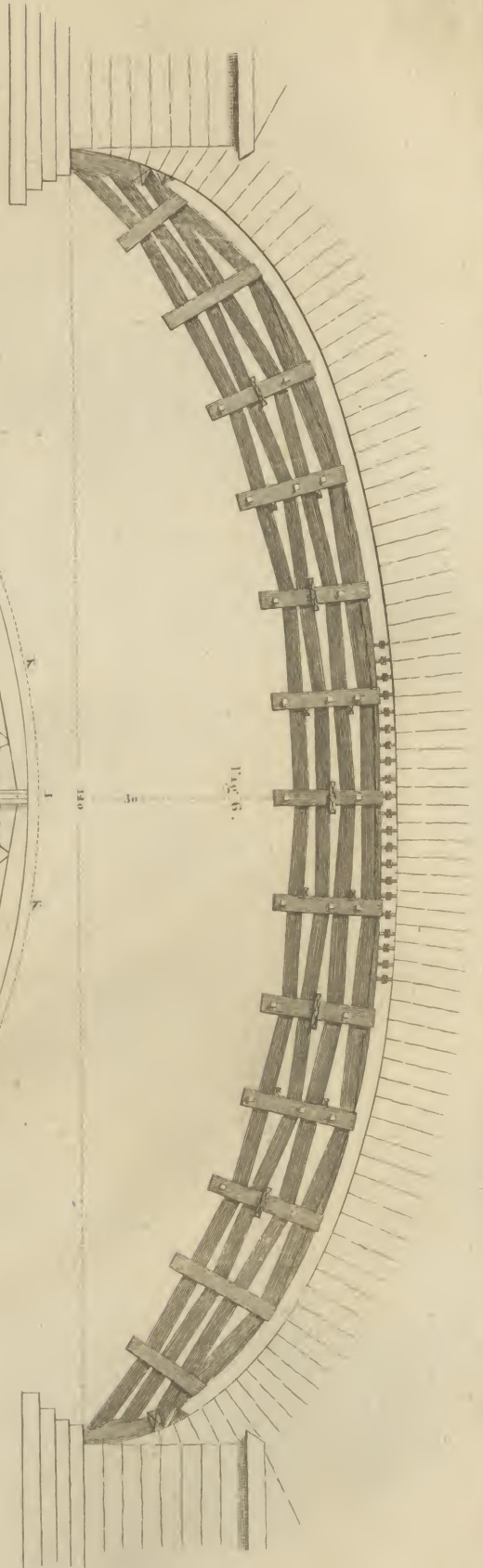
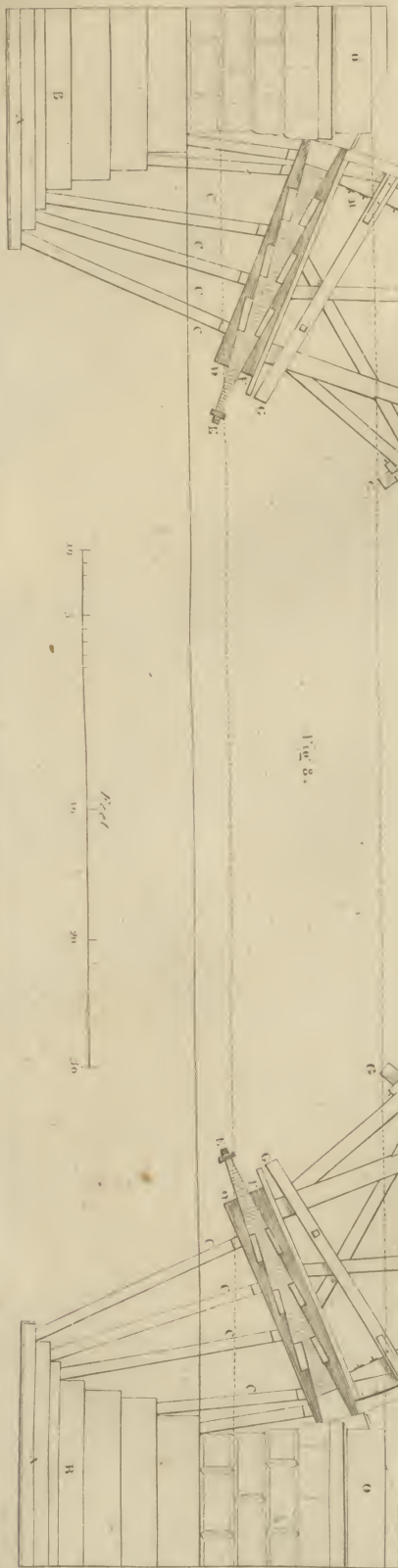


Fig. 7.





140

30

Fig. 6.

Fig. 9.

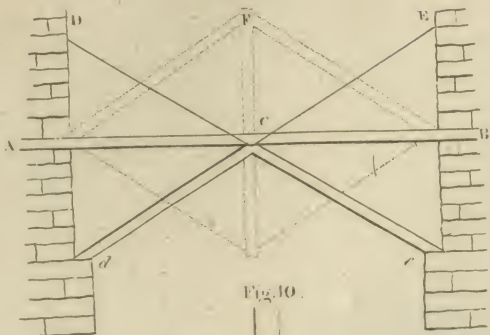


Fig. 11.

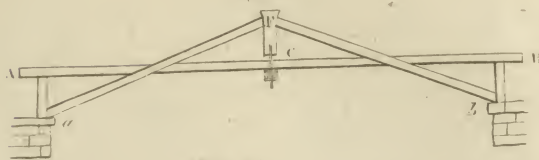


Fig. 10.

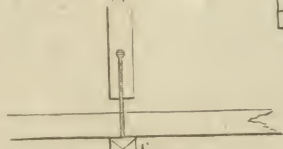


Fig. 14.

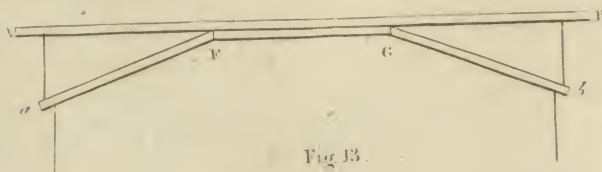


Fig. 13.

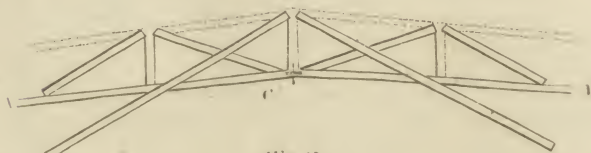


Fig. 12.



Fig. 15.

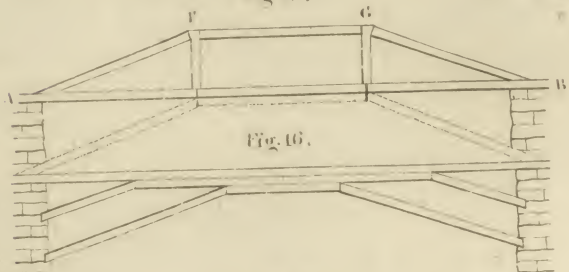


Fig. 17.



Fig. 16.

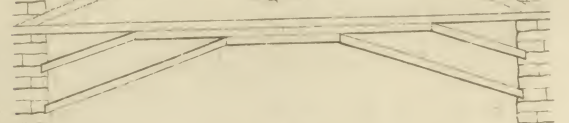


Fig. 23.

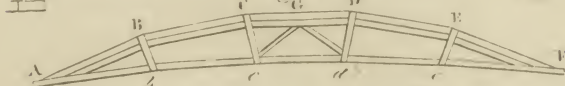


Fig. 22.



Fig. 18.

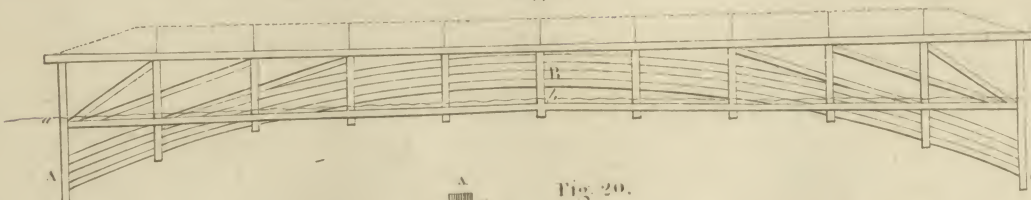


Fig. 20.

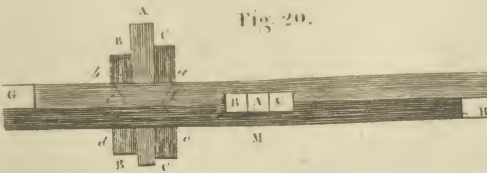


Fig. 19.

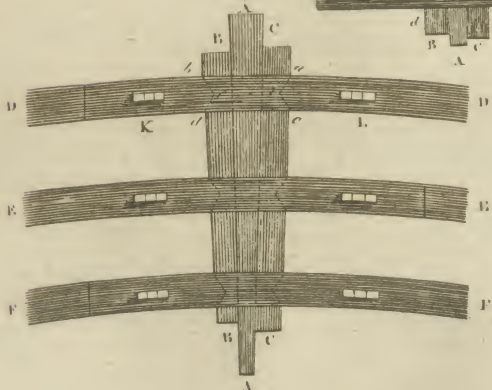
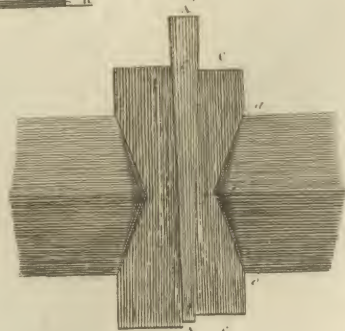
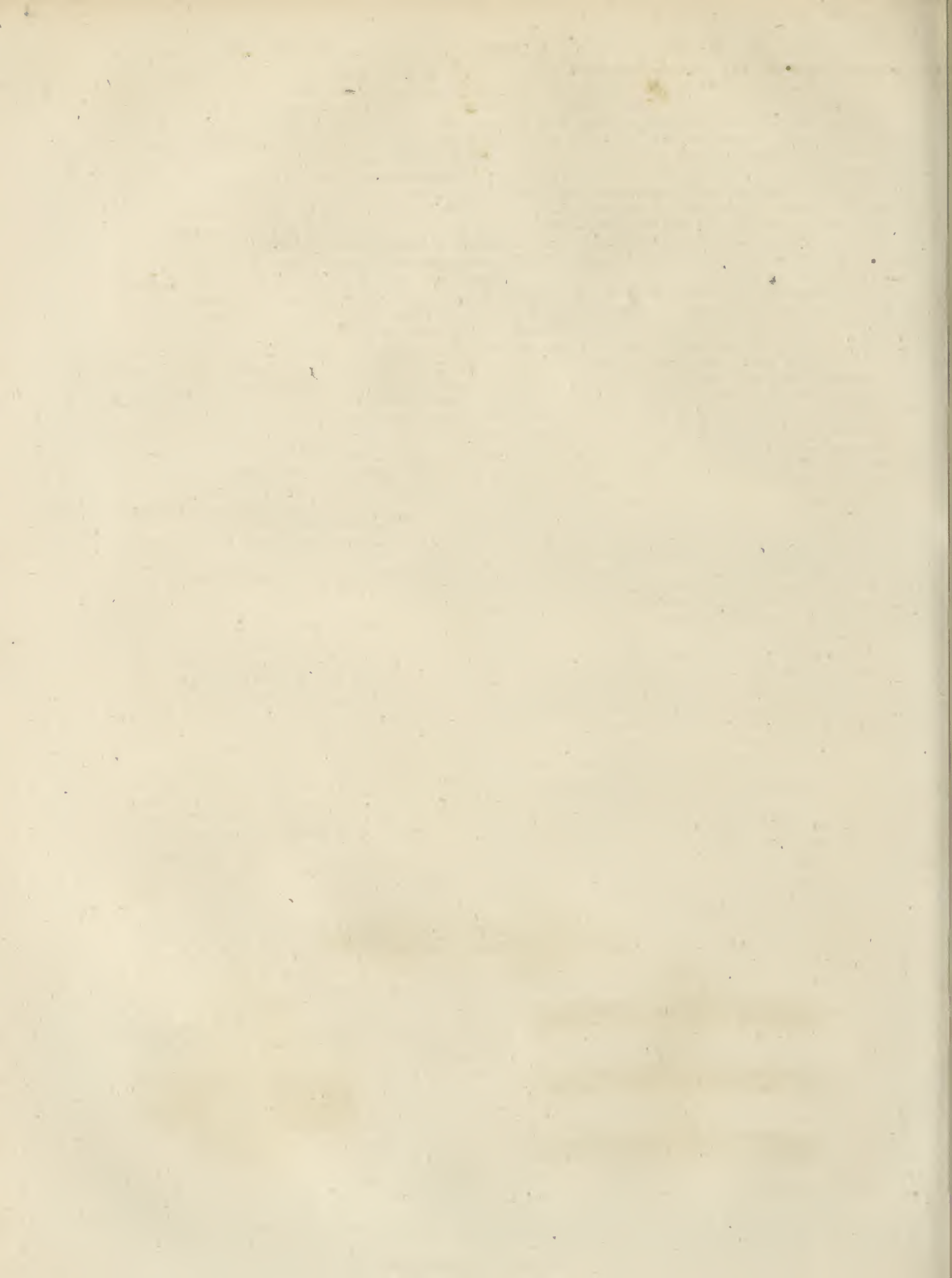


Fig. 21.





Center.

may be taken out, and replaced by another, without disturbing the rest, and without the smallest risk. On the whole, we think it a very valuable addition to British carpentry. The method here practised, both for joining the parts of one beam and for framing the different beams together, suggests the most firm and light constructions for dome-roofs that can be conceived; incomparably superior to any that have yet been erected. The whole may be framed, without a nail or a spike, into one net-like shell that cannot even be pulled in pieces. We may perhaps consider this in another article; at present we return to the consideration of trussed bridges.

42
Bridges
combined
by simple
addition or
by compo-
sition.

When the width of the river exceeds what is thought practicable by a single truss, we must then combine, either by simple addition, or by composition, different trusses together. We compose a bridge by simple addition when we make a frame of carpentry of an unchangeable and proper shape, to serve as one of the archstones of a bridge of masonry. This may easily be comprehended by looking at fig. 22. Each of the frames A, B, C, D, must be considered as a separate body, and all are supported by their mutual abutment. The nature of the thing is not changed, although we suppose that the rails of the frame B, instead of being mortised into an upright *b' b'*, unconnected with the frame C, is mortised into the upright *c c* of that frame, the direction and intensity of the mutual pressures of the two frames are the same in both cases; accordingly this is a very common form of small wooden bridges. It is usual, indeed, to put diagonal battens into each; but we believe that this is more frequently done to please the eye than to produce an unalterable shape of each frame.

To an unskilful carpenter this bridge does not seem essentially different from the centering of Mr Hupeau for the bridge of Orleans; and indeed, in many cases, it requires reflection, and sometimes very minute reflection, to distinguish between a construction which is only an addition of frame to frame till the width be covered, from a construction where one frame works on the adjoining one transversely, pushing it in one part, and drawing it in another. The ready way for an unlettered artist to form a just notion of this point, is to examine whether he may saw through the connecting piece *b' b'* from one end to the other, and make them two separate frames. Whenever this cannot be done without that part opening, it is a construction by composition. Some of the beams are on the stretch; and iron straps, extending along both pieces, are necessary for securing the joint. The bridge is no longer a piece of masonry, but a performance of pure carpentry, depending on principles peculiar to that art. Equilibration is necessary in the first construction; but, in the second, any inequality of loading is made ineffectual for hurting the edifice, by means of the stretch that is made to operate on some other piece. We are of opinion, that this most simple employment of the distinguishing principle of carpentry, by which the beams are made to act as ties, will give the most perfect construction of a wide bridge. One polygon alone should contain the whole of the abutments; and one other polygon should consist entirely of ties; and the beams which form the radii, connecting the angles of the two polygons, complete the whole. By confining the atten-

43
How to dis-
tinguish
bridges
formed ac-
cording to
these diffe-
rent me-
thods.

tion to these two simple objects, the abutments of the outer polygon, and the joints of the inner one, may be formed in the most simple and efficient manner, without any collateral connections and dependencies, which divide the attention, increase the complication, and commonly produce unexpected and hurtful strains. It was for this reason that we have so frequently recommended the centering of the bridge of Orleans. Its office will be completely performed by a truss of the form of fig. 23.; where the polygon ABCDEF, consisting of two layers of beams (if one is not sufficient), contains the whole abutments, and the other *A b c d e F* is nothing but an iron rod. In this construction, the obtuseness of the angles of the lower polygon is rather an advantage. The braces *G c*, *G d*, which are wanted for trussing the middle of the outer beams, will effectually secure the angles of the exterior polygon against all risk of change. The reader must perceive that we have now terminated in the construction of the Norman roof. We indeed think it the best general form, when some moderate declivity is not an insuperable objection. When this is the case, we recommend the general plan of the centering of the bridge of Orleans. We would make the bridge (we speak of a great bridge) consist of four trusses; two to serve as the outsides of the bridge, and two inner trusses, separating the carriage-way from the foot-paths. The road should follow the course of the lower polygon, and the main truss should form the rails. It might look strange; but we are here speaking of strength; and evident, but not unwieldy, strength, once it becomes familiar, is the surest source of beauty in all works of this kind.

Center.

44
The best
general
form of a
wooden
bridge.

CENTRE of Friction, is that point in the base of a body on which it revolves; into which, if the whole surface of the base, and the mass of the body, were collected, and made to revolve about the centre of the base of the given body, the angular velocity destroyed by its friction would be equal to the angular velocity destroyed in the given body by its friction in the same time. See FRICTION in this Supplement.

CENTRE of Gyration, is that point in which, if the whole mass be collected, the same angular velocity will be generated in the same time, by a given force acting at any place, as in the body or system itself. This point differs from the centre of oscillation, in as much as in this latter case the motion of the body is produced by the gravity of its own particles; but, in the case of the centre of gyration, the body is put in motion by some other force acting at one place only.

CENTRE of Oscillation, is that point in the axis or line of suspension of a vibrating body, or system of bodies, in which, if the whole matter or weight be collected, the vibrations will still be performed in the same time, and with the same angular velocity, as before. Hence, in a compound pendulum, its distance from the point of suspension is equal to the length of a simple pendulum whose oscillations are isochronal with those of the compound one.

CENTRE of Pressure, of a fluid against a plane, is that point against which a force being applied equal and contrary to the whole pressure, it will just sustain it, so as that the body pressed on will not incline to either side.—This is the same as the centre of percussion, supposing the axis of motion to be at the intersection of this plane with the surface of the fluid; and the centre

Centrob-
rico
||
Chambers.

of pressure upon a plane parallel to the horizon, or upon any plane where the pressure is uniform, is the same as the centre of gravity of that plane.

CENTROBARICO, the same as centre of gravity.

CENTROBARIC METHOD, is a method of determining the quantity of a surface or solid, by means of the generating line or plane and its centre of gravity. The doctrine is chiefly comprised in this theorem :

Every figure, whether superficial or solid, generated by the motion of a line or plane, is equal to the product of the generating magnitude and the path of its centre of gravity, or the line which its centre of gravity describes.

CERUSE, or **WHITE-LEAD**, is a substance so much used in painting, and for other purposes, that numerous modes have been employed for the preparation of it. Of the most common of these, a sufficient account has been given in the *Encyclopædia* (see **CERUSE**, and the same word *CHEMISTRY-Index*); but Lord Dundonald has discovered a more expeditious and facile method than any of them, which becomes the more useful, as the substance with which it is effected has been hitherto rejected by the chemical world as a *caput mortuum*.

His lordship directs common lead to be reduced to a calx, but not too fine, and to have a proportion of five-sixth parts thereof, intimately mixed with muriat, or solution of potash. In this state, he directs it to be frequently stirred, in order to have the new surfaces of the mixture exposed to the carbonic acid of atmospheric air; as his lordship observes, that the effects of the carbonic acid on the alkali existing in the present state of the mixture is essentially necessary, in order to effect the intended purpose. In this state it is to be frequently sprinkled with water, and, after the calx has been long enough immersed with the muriat to be sufficiently operated upon, the muriat is to be levigated by common water from the calx, and to be concentrated by evaporation, in order to be made use of at a future period with other calx. The calx is to be afterwards ground, levigated, and dried for use.

For this discovery, his lordship obtained a patent on the 18th of August 1797; and the success which has attended the former patents of this scientific nobleman leads us to conclude, that the present discovery is entitled to the attention of the public.

CHAMBERS (Sir William), the celebrated architect, was descended of the ancient family of Chalmers in Scotland, barons of Tartas in France. His grandfather suffered considerably in his fortune by supplying Charles XII. of Sweden with money, &c. which that monarch repaid in base coin. Sir William's father resided several years in Sweden to recover his claims; and there Sir William was born, and, at eighteen years of age, appointed supercargo to the Swedish East India company. From a voyage which he made to China, he brought home the Asiatic style of ornament, in tents, temples, mosques, and pagodas. These ornaments (through the interest of Lord Bute) he was enabled to apply in the gardens at Kew. Patronised by the princess dowager and the king, Mr Chambers had much of the fashionable business of the day. Under Burke's reform, he was appointed surveyor-general of the board of works. Somerfet-house was worth to him at least L. 2000 a-year. His *Chef d'œuvres* are his staircases, particularly those at Lord Beborough's,

Lord Gower's, and the Royal and Antiquarian Societies. The terrace behind Somerfet-house is a bold effort of conception. His designs for interior arrangements were excellent. His *Treatise on Civil Architecture* alone will immortalize his name. In private life, Sir William was hospitable, kind, and amiable. His son married Miss Rodney; Mr Cotton, Mr Innis, and Mr Harward, married his beautiful daughters. Having been abstemious in his youth, Sir William's constitution did not begin to break till he was seventy years of age. For the last three years, he was kept alive by wine and oxygenated air; and died on the 5th of March 1796. His celebrity will be lasting in the works which he has left; and as he was equally skilled in the theory and practice of the arts which he professed, his precepts are as valuable as his works. At his death, he was fellow of the Royal and Antiquarian Societies, treasurer of the Royal Academy, surveyor-general of the board of works, and knight of the Swedish order of the Polar Star.

CHAMFER, or **CHAMFERET**, an ornament in architecture, consisting of half a scotia; being a kind of furrow or gutter on a column.

UNIVERSAL CHARACTERS, could they be introduced, would contribute so much to the diffusion of useful knowledge, that every attempt to make such a scheme simple and practicable is at least intitled to notice. Accordingly, in the *Encyclopædia Britannica*, under the word **CHARACTER**, a short account is given of the principal plans of universal characters which had then fallen under our observation; but since that article was published, a new method of writing, by which the various nations of the earth may communicate their sentiments to each other, has been proposed by *Thomas Northmore, Esq.* of Queen-street, Mayfair. It bears some resemblance to that which we have given from the *Journal Littéraire*, 1720, but it is not the same; and of the two, Mr Northmore's is perhaps the most ingenious. The ground-work of the superstructure differs not indeed from that of the journal, being this in both, "That if the same numerical figure be made to represent the same word in the various languages upon earth, an universal character is immediately obtained." The only objection which the author or his friends saw to such a plan, originates in the diversity of idioms; but, as he truly observes, every schoolboy has this difficulty to encounter as often as he construes Terence.

Such then was Mr Northmore's original plan: but he soon perceived that it was capable of considerable improvement; for, instead of using a figure for every word, it will be necessary to apply one only to every useful word; and we all know how few words are absolutely necessary to the communication of our thoughts. Even these may be much abbreviated by the adoption of certain uniform fixed signs (not amounting to above 20), for the various cases, numbers, genders, degrees of comparison, of nouns, tenses, and moods of verbs, &c. All words of negation, too, may be expressed by a prefixed sign. A few instances will best explain the author's meaning.

Suppose the number 5 to represent the word *see*.

6	—	—	a man,
7	—	—	happy,
8	—	—	never,
9	—	—	I.

Chamfer,
Character

Characters. " I would then (says he) express the tenses, genders, cases, &c. in all languages, in some such uniform manner as following :

(1)	5	=	present tense,	—	fee,
(2)	.5	=	perfect tense,	—	saw,
(3)	:5	=	perfect participle,	—	seen,
(4)	5:	=	present participle,	—	seeing,
(5)	5.	=	future,	— —	will see,
(6)	<u>5</u>	=	substantive,	—	sight,
(7)	<u>5</u>	=	personal substantive,	—	spectator,
(8)	<u>6</u>	=	nominative case,	—	a man,
(9)	<u>6</u>	=	genitive,	— —	of a man,
(10)	<u>6</u>	=	dative,	— —	to a man,
(11)	<u>6</u>	=	feminine,	— —	a woman,
(12)	+6	=	plural,	— —	men,
(13)	7	=	positive,	— —	happy,
(14)	[^] 7	=	comparative,	—	happier,
(15)	[^] 7	=	superlative,	—	happiest,
	<u>7</u>	=	as above, No. 6.	—	happiness,
(16)	-7	=	negation,	— —	unhappy.

" From the above specimen, I should find no difficulty in comprehending the following sentence, though it were written in the language of the Hottentots :

9, 8, .5, —[^]7, 6. *I never saw a more unhappy woman.*

" Those languages which do not use the pronoun prefixed to the verb, as the Greek and Roman, &c. may apply it, in a small character, simply to denominate the person ; thus, instead of 9, 8, .5, *I never saw* ; they may write, 8, ⁹.5, which will signify that the verb is in the first person, and will still have the same meaning."

Our author seems confident that, according to this scheme of an universal character, about 20 signs, and less than 10,000 chosen words (synonyms being set aside), would answer all the ends proposed ; and that foreigners, by referring to their numerical dictionary, would easily comprehend each other. He proceeds next to shew how appropriate sounds may be given to his

signs, and an universal living language formed from the universal characters. Characters
||
Chemis.

To attain this end, he proposes to distinguish the ten numerals by ten monosyllabic names of easy pronunciation, and such as may run without difficulty into one another. To illustrate his scheme, however, he calls them, for the present, by their common English names ; but would pronounce each number made use of by uttering separately its component parts, after the manner of accountants. Thus let the number 6943 represent the word *horse*, he would not, in the universal language, call a horse *six thousand nine hundred and forty-three*, but *six, nine, four, three*, and so on for all the words of a sentence, making the proper stop at the end of each. In the same manner, a distinct appellation must be appropriated to each of the prefixed signs, to be pronounced immediately after the numeral to which it is an appendage. Thus if *plu* be the appellation or the sign of the plural number, *six, nine, four, three, plu* will be *horses*.

" Thus (says our author), I hope it is evident that about 30 or 40 distinct syllables are sufficient for the above purpose ; but I am much mistaken if *eleven* only will not answer the same end. This is to be done by substituting the first 20 or 30 numerals for the signs, and saying, as in algebra, that a term is in the power of such a number, which may be expressed by the simple word *under*. *Ex. gr.* Let 6943 represent the word *horse* ; and suppose four to be the sign of the plural number, I would write the word thus, 6943^4 ; and pronounce it, *six, nine, four, three*, in the power of or *under* four. By these means eleven distinct appellations would be sufficient, and time and use would much abbreviate the pronunciation."

To refuse the praise of ingenuity to this contrivance for an universal language would be very unjust ; but elocution in this manner would be so very tedious, that surely the author himself, when he thinks more coolly on the subject, will perceive, that in the living speech its defects would more than balance its advantages. A *pangraph*, as he calls his universal character, would indeed be useful, and is certainly practicable ; a *panleg* (if we may form such a word) would not be very useful, unless it were much more perfect than it could be made according to the plan before us.

CHAUSETRAPPE. See *CROW'S Feet*, Encycl.

CHEMIN DES RONDS, in fortification, the way of the rounds, or a space between the rampart and the low parapet under it, for the rounds to go about it.

CHEMISTRY,

¹ Definition. **I**S a science, the object of which is to ascertain the ingredients that enter into the composition of bodies, to examine the nature of these ingredients, the manner in which they combine, and the properties resulting from their combination.

As an art, it has been in some measure coeval with the human race; for many of the most important branches of manufactures could not have been conducted without at least some knowledge of chemical combinations. As a science, it can hardly be dated farther back than the middle of the 17th century; but since that time it has advanced with a rapidity altogether unprecedented in the annals of philosophy. Newton laid its foundation; and since his days an almost incredible number of the most distinguished names in Europe have enlisted under its banners. So rapid has this progress been, that though the article CHEMISTRY in the *Encyclopædia Britannica* was written only about ten years ago, the language and reasoning of chemistry have been so greatly improved, and the number of facts have accumulated so much, that we find ourselves under the necessity of tracing over again the very elements of the science.

² Importance of chemistry. **I**ndeed, if we consider the importance of chemistry, we shall not be so much surprised at the ardour with which it has been cultivated. As a science, it is intimately connected with all the phenomena of nature; the causes of rain, snow, hail, dew, wind, earthquakes: even the changes of the seasons can never be explored with any chance of success while we are ignorant of chemistry; and the vegetation of plants, and some of the most important functions of animals, have received all their illustration from the same source. No study can give us more exalted ideas of the wisdom and goodness of the Great First Cause than this, which shews us everywhere the most astonishing effects produced by the most simple though adequate means, and displays to our view the great care which has everywhere been taken to secure the comfort and happiness of every living creature. As an art, it is intimately connected with all our manufactures: The glass-blower, the potter, the smith, and every other worker in metals, the tanner, the soap-maker, the dyer, the bleacher, are real-

ly practical chemists; and the most essential improvements have been introduced into all these arts by the progress which chemistry has made as a science. Agriculture can only be improved rationally and certainly by calling in the assistance of chemistry; and the advantages which medicine has derived from the same source are too obvious to be pointed out.

It is evident from the definition of chemistry that it ³ must consist in a history of the simple substances which enter into the composition of bodies, in an investigation of the manner in which these substances combine, and in a description of the properties of the compounds which they form. And this is the arrangement which we mean to pursue; referring to ourselves, however, the liberty of deviating a little from it, whenever it may appear necessary for the sake of perspicuity. All our classifications are in fact artificial; nature does not know them, and will not submit to them. They are useful, however, as they enable us to learn a science sooner, and to remember it better; but if we mean to derive these advantages from them, we must renounce a rigid adherence to arbitrary definitions, which nature disclaims.

We shall begin by an account of the simplest bodies, and proceed gradually to those which are more compound. By *simple bodies*, we do not mean what the ancient philosophers called the *elements of bodies*, but merely substances which have not yet been decomposed. Very possibly the bodies which we reckon simple may be real compounds; but till this has actually been proved, we have no right to suppose it. Were we acquainted with all the elements of bodies, and with all the combinations of which these elements are capable, the science of chemistry would be as perfect as possible; but at present this is very far from being the case.

We shall divide this article into four parts. The *first* part shall treat of those bodies which are at present considered as simple; the *second*, of those bodies which are formed by the union of two simple bodies, and which, for want of a better word we shall call *compound bodies*; the *third*, of those bodies which are formed by the union of two compound bodies; and the *fourth*, of bodies such as they are presented to us by nature in the mineral, vegetable, and animal kingdoms.

PART I. OF SIMPLE BODIES.

⁴ Classes of simple bodies. **A**LL the bodies which are at present reckoned simple, because they have never been decomposed, may be reduced into six classes.

- | | |
|-------------------------|-------------|
| 1. Oxygen, | 4. Earths, |
| 2. Simple combustibles, | 5. Caloric, |
| 3. Metals, | 6. Light. |

These shall form the subjects of the six following chapters.

CHAP. I. OF OXYGEN.

⁵ Method of procuring oxygen. **T**AKE a quantity of nitre, or saltpetre, as it is also called, and put it into a gun-barrel A (fig. 1.), the

touch-hole of which has been previously closed up with metal. This barrel is to be bent in such a manner, that while the close end, in which the nitre lies, is put into the fire E, the open end may be plunged below the surface of the water, with which the vessel B is filled. At the same time, the glass jar D, previously filled with water, is placed on the support C, lying at the bottom of the vessel of water B, so as to be exactly over the open end of the gun-barrel A. As soon as the nitre becomes hot, it emits a quantity of air, which issuing from the end of the gun-barrel, ascends to the top of the glass jar D, and gradually displaces all the water. The glass jar D then appears to be empty, but is in fact filled with air. It may then be removed in the following

Part I.

Oxygen. ing manner: Slide it away a little from the gun-barrel and the support, and then dipping any flat dish into the water below it, raise it on it, and bear it away. The dish must be allowed to retain a quantity of water in it, (see fig. 2.) Another jar may then be filled with air in the same manner; and this process may be continued either till the nitre ceases to give out air, or till as many jarfuls have been obtained as are required. This method of obtaining and confining air was first invented by Dr Mayow, and afterwards much improved by Dr Hales. All the airs obtained by this or any other process, or, to speak more properly, all the airs differing from the air of the atmosphere, have, in order to distinguish them from it, been called *gases*, and this name we shall afterwards employ.

6 The gas which we have obtained by the above process was discovered by Dr Priestley on the 1st of August 1774, and called by him *dephlogisticated air*. Mr Scheele of Sweden discovered it in 1775, without any previous knowledge of what Dr Priestley had done: he gave it the name of *empyreal air*. Condorcet, so conspicuous during the French revolution, gave it first the name of *vital air*; and Mr Lavoisier afterwards called it *oxygen gas*; a name which is now generally received, and which we shall adopt.

Oxygen gas may be obtained likewise by the following process:

7 **Another method.** D (in fig. 3.) represents a wooden trough, the inside of which is lined with lead or tinned copper. AB is a shelf running along the inside of it, about three inches from the top. C is the cavity of the trough, which ought to be a foot deep. It is to be filled with water at least an inch above the shelf AB. In the body of the trough, which may be called the cistern, the jars destined to hold gas are to be filled with water, and then to be lifted, and placed inverted upon the shelf at B, with their edges a little over it. This trough, which was invented by Dr Priestley, has been called by the French chemists the *pneumato-chemical*, or simply *pneumatic apparatus*, and is extremely useful in all experiments in which gases are concerned. Into the glass vessel E put a quantity of the black oxide (A) of manganese in powder, and pour over it as much of that liquid which in commerce is called *oil of vitriol*, and in chemistry *sulphuric acid*, as will somewhat more than cover it. Then insert into the mouth of the vessel the glass tube F, so closely that no air can escape except through the tube. This may be done by covering the joining with a paste made of wheat-flour and water, or any other *lute*, as substances used for similar purposes are called. The end of the tube C is then to be plunged into the pneumatic apparatus D, and the jar G, previously filled with water, to be placed over it on the shelf. The whole apparatus being fixed in that situation, the glass vessel E is to be heated by means of a lamp or a candle. A great quantity of oxygen gas rushes along the tube F, and fills the jar G. As soon as the jar is filled, it may be slid to another part of the shelf, and other jars substituted in its place, till as much gas has been obtained as is wanted.

8 **Properties of oxygen.** 1. Oxygen gas is colourless, and invisible like com-

mon air. Like it too, it is elastic, and capable of infinite expansion and compression. **Oxygen.**

2. If a lighted taper be let down into a jar of oxygen gas, it burns with such splendor that the eye can scarcely bear the glare of light, and at the same time time produces a much greater heat than when burning in common air. It is well known that a candle put into a well closed jar, filled with common air, is extinguished in a few seconds. This is the case also with a candle enclosed in oxygen gas; but it burns much longer in an equal quantity of that gas than of common air.

3. It was proved long ago by Boyle, that animals cannot live without air, and by Mayow that they cannot breathe the same air for any length of time without suffocation. Dr Priestley and several other philosophers have shewn us, that animals live much longer in the same quantity of oxygen gas than of common air. Count Morozzo placed a number of sparrows, one after another, in a glass bell filled with common air, and inverted over water.

	H.	M.
The first sparrow lived	-	3 0
The second	-	0 3
The third	-	0 1

He filled the same glass with oxygen gas, and repeated the experiment.

	H.	M.
The first sparrow lived	-	5 23
The second	-	2 10
The third	-	1 30
The fourth	-	1 10
The fifth	-	0 30
The sixth	-	0 47
The seventh	-	0 27
The eighth	-	0 30
The ninth	-	0 22
The tenth	-	0 21

He then put in two together; the one died in 20 minutes, but the other lived an hour longer.

4. Atmospheric air contains about 27 parts in the hundred of oxygen gas. This was first discovered by Scheele. It has been proved by a great number of experiments, that no substance will burn in common air previously deprived of all the oxygen gas which it contained; but combustibles burn with great splendor in oxygen gas, or in other gases to which oxygen gas has been added. Oxygen gas then is absolutely necessary for combustion.

5. It has been proved also, by many experiments, that no breathing animal can live for a moment in any air or gas which does not contain oxygen mixed with it. Oxygen gas then is absolutely necessary for respiration.

6. When substances are burnt in oxygen gas, or in any other gas containing oxygen, if the air be examined after the combustion, a great part of the oxygen will be found to have disappeared. If charcoal, for instance, be burnt in oxygen gas, there will be found, instead of part of the oxygen, another very different gas, known by the name of carbonic acid gas. Exactly the same thing takes place when air is respired by animals; part of the oxygen gas disappears, and its place is occupied by substances possessed of very different properties. **Oxygen gas.**

(A) This substance shall be afterwards described. It is now very well known in Britain, as it is in common use with bleachers and several other manufacturers.

¹² Oxygen. gas then undergoes some change during combustion, as well as the bodies which have been burnt; and the same observation applies also to respiration (B).

¹² Its specific gravity. 7. The specific gravity of oxygen gas, as determined by Mr Kirwan*, is 0,00135, that of water being 1,0000, as is always the case when specific gravity is mentioned absolutely. It is therefore 740 times lighter than the same bulk of water. Its weight to atmospheric air is as 1103 to 1000: 116 cubic inches of oxygen gas weigh 59,03 grains troy, 116 cubic inches of common air, 35,38 grains.

¹³ Affinity explained. 8. Oxygen is capable of combining with a great number of bodies, and forming compounds. As the combination of bodies is of the utmost importance in chemistry, before proceeding farther we shall attempt to explain it. When common salt is thrown into a vessel of pure water, it melts, and very soon spreads itself through the whole of the liquid, as any one may convince himself by the taste. In this case the salt is combined with the water, and cannot afterwards be separated by filtration or any other method merely mechanical. It may, however, by a very simple process: Pour into the solution a quantity of spirit of wine, and the whole of the salt instantly falls to the bottom.

Why did the salt dissolve in water, and why did it fall to the bottom on pouring in spirit of wine? These questions were first answered by Sir Isaac Newton. There is a certain attraction between the particles of common salt and those of water, which causes them to unite together whenever they are presented to one another. There is an attraction also between the particles of water and of spirit of wine, which equally disposes them to unite, and this attraction is greater than that between the water and salt; the water therefore leaves the salt to unite with the spirit of wine, and the salt being now unsupported, falls to the ground by its gravity. This power, which disposes the particles of different bodies to unite, was called by Newton *attraction*, by Bergman, *elective attraction*, and by many of the German and French chemists, *affinity*; and this last term we shall employ, because the other two are rather general. All substances which are capable of combining together are said to have an *affinity for* (c) each other: those substances, on the contrary, which do not unite, are said to have *no affinity* for each other. Thus there is no affinity between water and oil. It appears from the instance of the common salt and spirit of wine, that substances differ in the degree of their affinity for other substances, since the spirit of wine displaced the salt and

united with the water. Spirit of wine therefore has a stronger affinity for water than common salt has.

In 1719 Geoffroi invented a method of representing the different degrees of affinities in tables, which he called *tables of affinity*. His method consisted in placing the substances whose affinities were to be ascertained at the top of a column, and the substances with which it united below it, each in the order of its affinity; the substance which had the strongest affinity next it, and that which had the weakest farthest distant, and so of the rest. According to this method, the affinity of water for spirit of wine and common salt would be marked as follows:

WATER,
Spirit of wine,
Common salt.

This method has been universally adopted, and has contributed very much to the rapid progress of chemistry.

We shall proceed therefore to give a table of the affinities of oxygen.

OXYGEN,
Carbon,
Zinc,
Iron,
Manganese,
Hydrogen,
Azot,
Sulphur,
Phosphorus,
Cobalt,
Nickel,
Lead,
Tin,
Phosphorous acid,
Copper,
Bismuth,
Antimony,
Mercury,
Silver,
Arsenic,
Sulphurous acid,
Oil,
Nitrous gas,
Gold,
White oxide of arsenic,
Muriatic acid,
Oxide of tin,

White

(B) Mayow had in the last century made considerable progress towards the discovery of oxygen gas. He knew that only a part of the air supported combustion: This part he called *particula igneo-aerea*. He knew that this part was contained in nitre: "Pars nitri aerea nihil aliud quam particulae ejus igneo-aeræ est." He adds, "At non est estimandum pabulum igneo-aereum ipsum aerem esse, sed tantum partem ejus majus activam subtilemque. Quippe lucerna vitro inclusa expirat cum tamen copia aeris satis ampla in eodem continetur." He knew also that it was this part of the air which was useful in respiration. After mentioning several experiments to prove this, he adds, "Ex dictis certo constat animalia respirando particulas quasdam vitales easque elasticas ab aere haurire." See his *Traclatus quinque Medico-Physici*, p. 12. and 106.—He knew also that this part of the air was necessary to combustion: "Et tamen certo constat, particulas nitro-aereas non minus quam sulphureas ad ignem conflandum necessarias esse." *Ibid*, p. 26.

(c) We are not certain that the phrase *affinity for* is warranted by classical authority; we have ventured, however, to use it, because, as the word *affinity* in this article signifies a species of attraction, we thought it would be more perspicuous to put after it the preposition *for*, which usually follows the word *attraction*, than *to* or *with*, which come after *affinity* when used in its ordinary acceptation.

Part I.

Sulphur.

White oxide of lead?
Nitrous acid,
White oxide of manganese,
Water.

The reason of this order will appear when we treat of these various substances.

CHAP. II. Of SIMPLE COMBUSTIBLE BODIES.

¹⁵ Five simple combustibles. BY *combustibles*, we mean substances capable of combustion; and by *simple combustibles*, bodies of that nature which have not yet been decomposed. These are only five in number, SULPHUR, PHOSPHORUS, CARBON, HYDROGEN, and AZOT. Were we to adhere strictly to our definition indeed, we should add all the metals; for they are also combustible, and have not yet been decomposed: But for the reasons formerly given, we shall venture to deviate a little from strict logic, and consider them afterwards as a distinct class of substances.

SECT. I. Of Sulphur.

SULPHUR, distinguished also in English by the name of *brimstone*, was known in the earliest ages. As it is found native in many parts of the world, it could not fail very soon to attract the attention of mankind. It was used by the ancients in medicine, and its fumes were employed in bleaching wool*.

* Pliny.
lib. xxxv.
c. 15.

¹⁶ Properties of sulphur.

Sulphur is a hard brittle substance, commonly of a yellow colour, without any smell, and of a weak though perceptible taste. It is a non-conductor of electricity, and of course becomes electric by friction.

† *Fourcroy*. If a considerable piece of sulphur be exposed to a sudden though gentle heat, by holding it in the hand, for instance, it breaks to pieces with a crackling noise †.

Its specific gravity is 1,990.

When heated to the temperature of 185° of Fahrenheit, it melts and becomes very fluid. If the temperature be still farther increased, the fluidity diminishes; but when the sulphur is then carried from the fire and allowed to cool, it becomes as fluid as ever before it cools †.

† *Dr Black*.

When sulphur is heated to the temperature of 170°, it rises up in the form of a fine powder, which may be easily collected in a proper vessel. This powder is called *flowers of sulphur*. When substances fly off in this manner on the application of a moderate heat, they are called *volatile*; and the process itself, by which they are raised, is called *volatilization*.

¹⁷ Flowers of sulphur.

Sulphur undergoes no change by being allowed to remain exposed to the open air.

When thrown into water, it does not melt, as common salt does, but falls to the bottom, and remains there unchanged; it is therefore *insoluble* in water. If, however, it be poured, while in a state of fusion, into water, it assumes a red colour, and retains such a degree of softness, that it may be kneaded between the fingers; but it loses this property in a few days †.

† *Fourcroy*.

¹⁸ Sulphur capable of crystallizing. There are a great many bodies which, after being dissolved in water or melted by heat, are capable of assuming certain regular figures. If a quantity of common

salt, for instance, be dissolved in water, and that fluid, by the application of a moderate heat, be made to fly off in the form of steam; or, in other words, if the water be slowly *evaporated*, the salt will fall to the bottom of the vessel in cubes. These regular figures are called *crystals*. Now sulphur is capable of crystallizing. If it be melted, and as soon as its surface begins to congeal, the liquid sulphur beneath be poured out, the internal cavity will exhibit long needle-shaped crystals of an octahedral figure. This method of crystallizing sulphur was contrived by Rouelle.

Sulphur.

When sulphur is heated to the temperature of 302° in the open air, it takes fire spontaneously, and burns with a pale blue flame, and at the same time emits a great quantity of fumes of a very strong suffocating odour. When heated to the temperature of 570°, or a little higher, it burns with a bright white flame, and at the same time emits a vast quantity of fumes. If the heat be continued long enough, the sulphur burns all away without leaving any ashes or *residuum*. If the fumes be collected, they are found to consist entirely of *sulphuric acid*. By combustion, then, sulphur is converted into an acid. This fact was known several centuries ago, but no intelligible explanation was given of it till the time of Stahl. That chemist undertook the task; and founded on his experiments a theory so exceedingly ingenious, and supported by such a vast number of facts, that it was in a very short time adopted with admiration by all the philosophic world, and contributed not a little to raise chemistry to that rank among the sciences from which the ridiculous pretensions of the early chemists had excluded it.

¹⁹ Converted by combustion into an acid.

According to Stahl, there is only one substance in nature capable of combustion, which therefore he called *PHLOGISTON*; and all those bodies which can be set on fire contain less or more of it. Combustion is merely the separation of this substance. Those bodies which contain none of it are of course incombustible. All combustibles, except those which consist of pure phlogiston (if there be any such), are composed of an incombustible body and phlogiston united together. During combustion the phlogiston flies off, and the incombustible body remains behind. Now when sulphur is burnt, the substance which remains is sulphuric acid, an incombustible body. Sulphur therefore is composed of sulphuric acid and phlogiston.

²⁰ Stahl's explanation of this.

To establish this theory completely, it was necessary to shew that sulphur could be actually made by combining sulphuric acid and phlogiston; and this also Stahl undertook to perform. *Sulphat of potash* is a substance composed of sulphuric acid and potash (D), and *charcoal* is a combustible body, and therefore, according to the theory of Stahl, contains phlogiston: when burnt, it leaves a very inconsiderable residuum, and consequently contains hardly any thing else than phlogiston. He melted together in a crucible a mixture of *potash* and *sulphat of potash*, stirred into it one-fourth part by weight of pounded charcoal, covered the crucible with another inverted over it, and applied a strong heat to it. He then allowed it to cool, and examined its contents. The charcoal had disappeared, and there only remained in the crucible a mixture of potash and sulphur combined together,

(D) The nature of *potash* shall afterwards be explained. It is the *potash* well known in commerce in a state of purity.

^{Sulphur.} together, and of a darker colour than usual, from the residuum of the charcoal. Now there were only three substances in the crucible at first, potash, sulphuric acid, and charcoal: two of these have disappeared, and *sulphur* has been found in their place. Sulphur then must have been formed by the combination of these two. But charcoal consists of phlogiston and a very small residuum, which is still found in the crucible. The sulphur then must have been formed by the combination of sulphuric acid and phlogiston. This simple and luminous explanation appeared so satisfactory, that the composition of sulphur was long considered as one of the best demonstrated truths in chemistry.

²¹ Unsat-
isfactory. There are two facts, however, which Stahl either did not know or did not sufficiently attend to, neither of which were accounted for by his theory. The first is, that sulphur will not burn if air be completely excluded; the second, that sulphuric acid is heavier than the sulphur from which it was produced.

To account for these, or facts similar to these, succeeding chemists refined upon the theory of Stahl, deprived his phlogiston of *gravity*, and even assigned it a principle of *levity*. Still, however, the necessity of the contact of air remained unexplained. At last Mr Lavoisier, who had already distinguished himself by the extensiveness of his views, the accuracy of his experiments, and the precision of his reasoning, undertook the examination of this subject, and his experiments were published in the Memoirs of the Academy of Sciences for

²² Real expla-
nation by
Lavoisier. 1777. He put a quantity of sulphur into a large glass vessel filled with air, which he inverted into another vessel containing mercury, and then set fire to the sulphur by means of a burning-glass. It emitted a blue flame, and gave out thick vapours, but was very soon extinguished, and could not be again kindled. There was, however, a little sulphuric acid formed, which was a good deal heavier than the sulphur which had disappeared; there was also a diminution in the air of the vessel proportional to this increase of weight. The sulphur, therefore, during its conversion into an acid, must have absorbed part of the air. He then put a quantity of sulphuret of iron, which consists of sulphur and iron combined together, into a glass vessel full of air, which he inverted over water (E). The quantity of air in the vessel continued diminishing for eighteen days, as was evident from the ascent of the water to occupy the space which it had left; but after that period no farther diminution took place. On examining the sulphuret, it was found somewhat heavier than when first introduced into the vessel, and the air of the vessel wanted precisely the same weight. Now this air had lost all its oxygen; all the oxygen of the air in the vessel must therefore have entered into the sulphuret. Part of the sulphur was converted into sulphuric acid; and as all the rest of the sulphuret was unchanged, the whole of the increase of weight must have been owing to something which had entered into that part of the sulphur which was converted into acid. This something we know was oxygen. Sulphuric acid therefore must be composed of sulphur and oxygen; for as the original weight of the whole contents of the vessel remained exactly the

same, there was not the smallest reason to suppose that any substance had left the sulphur.

It is impossible, then, that sulphur can be composed of sulphuric acid and phlogiston, as Stahl supposed; since sulphur itself enters as a part into the composition of that acid. There must therefore have been some want of accuracy in the experiment by which Stahl proved the composition of sulphur, or at least some fallacy in his reasonings; for it is impossible that two contradictory facts can both be true. Upon examining the potash and sulphur produced by Stahl's experiment, we find them to be considerably lighter than the charcoal, sulphuric acid, and potash originally employed. Something therefore has made its escape during the application of the heat. And if the experiment be conducted in a close vessel, with a pneumatic apparatus attached to it, a quantity of gas will be obtained exactly equal to the weight which the substances operated on have lost; and this weight considerably exceeds that of all the charcoal employed. This gas is *carbonic acid gas*, which is composed of charcoal and oxygen, as will afterwards appear. We now perceive what passes in this experiment: Charcoal has a stronger affinity for oxygen at a high temperature than sulphur has. When charcoal therefore is presented to sulphuric acid in that temperature, the oxygen of the acid combines with it, they fly off in the form of carbonic acid gas, and the sulphur is left behind.

The combustion of sulphur, then, is nothing else than the act of its combination with oxygen; and, for any thing which we know to the contrary, it is a simple substance.

The affinities of sulphur, according to Bergman, are as follows: ²³ Affinities of sulphur.

Lead,
Tin,
Silver,
Mercury,
Arsenic,
Antimony,
Iron,
Fixed alkalis,
Ammonia,
Barytes,
Lime,
Magnesia,
Phosphorus?
Oils,
Ether,
Alcohol.

SECT. II. Of Phosphorus.

²⁴ Production
of phospho-
rus. LET a quantity of bones be burnt, or, as it is termed in chemistry, *calcined*, till they cease to smoke, or to give out any odour, and let them afterwards be reduced to a fine powder. Put this powder into a glass vessel, and pour sulphuric acid on it by little at a time, till farther additions do not cause any extrication of air bubbles (F). Dilute the mixture with a good deal of water, agitate it well, and keep it hot for some hours; then pass it through a filter. Evaporate the liquid slowly

(E) This experiment was first made by Scheele, but with a different view.

(F) The copious emission of air bubbles is called in chemistry *effervescence*.

Phos. horus slowly till a quantity of white powder falls to the bottom. This powder must be separated by filtration and thrown away. The evaporation is then to be resumed; and whenever any white powder appears, the filtration must be repeated in order to separate it. During the whole process, what remains on the filter must be washed with pure water, and this water added to the liquor. The evaporation is to be continued till all the moisture disappears, and nothing but a dry mass remains. Put this mass into a crucible, and keep it melted in the fire till it ceases to exhale sulphureous odours; then pour it out. When cold it assumes the appearance of a brittle glass. Pound this glass in a mortar, and mix it with one-third by weight of charcoal dust. Put this mixture into an earthen ware retort, and apply a receiver containing a little water. Put the retort into a sand bath, and increase the fire till it becomes red hot. A substance then passes into the receiver, which has the appearance of melted wax, and which congeals as it falls into the water of the receiver. This substance is *phosphorus*.

25
Its discovery.

* Leibnitz,
Mélange de
Berlin.

It was discovered by Brandt, a chemist of Hamburgh, about the year 1667, while he was employed in attempting to extract from human urine a liquid capable of converting silver into gold*. Kunkel, another German chemist, hearing of the discovery, was anxious to find out the process, and for that purpose associated himself with a friend of his named Kraft. But the latter procured the secret from the discoverer; and expecting by means of it to acquire a fortune, refused to give any information to his associate. Vexed at this treachery, Kunkel resolved to attempt the discovery himself; and though he knew only that phosphorus was obtained from urine, prosecuted the inquiry with so much zeal, that he succeeded, and has been deservedly considered as one of the discoverers†.

† Stahl's
Three Hundred Experiments.

Boyle likewise discovered phosphorus. Leibnitz indeed affirms that Kraft taught Boyle the whole process, and Kraft declared the same thing to Stahl. But surely the assertion of a dealer in secrets, and one who had deceived his own friend, on which the whole of this story is founded, cannot be put in competition with the affirmation of a man like Boyle, who was one of the honestest men, as well as greatest philosophers, of his age; and he positively assures us that he made the discovery without being previously acquainted with the process‡.

‡ Boyle Abridged by Shaw, iii. 174.
|| Bergman's Notes on Scheffer.

26
Its properties.

Gahn, a Swedish chemist, discovered, in 1769, that phosphorus was contained in bones||, and Scheele (G) very soon after invented a process for obtaining it from them. Phosphorus is now generally procured in that manner. The process described in the beginning of this section is that of the Dijon academicians: it differs from that of Scheele only in a single particular.

Phosphorus, when pure, is of a clear, transparent, yellowish colour; but when kept some time in water, it

becomes opaque, and then has a great resemblance to white wax. Its consistence is nearly that of wax: it may be cut with a knife or twilted to pieces with the fingers. It is insoluble in water. Its specific gravity is 1,714.

Phosphorus

It melts at the temperature of 99°*, and even at 67°* Pelletier, it gives out a white smoke, and is luminous in the dark; that is to say, it suffers a slow combustion: so that it can only be prevented from taking fire by keeping it in a very low temperature, or by allowing it to remain always plunged in water. If air be excluded, it evaporates at 219°, and boils at 554°†. When heated to 122° (H), it burns with a very bright flame, and gives out a great quantity of white smoke, which is luminous in the dark; at the same time it emits an odour which has some resemblance to that of garlic. It leaves no residuum; but when the white smoke is collected, it is found to be an acid. Stahl considered this acid as the muriatic (I). According to him, phosphorus was composed of muriatic acid and phlogiston, and the combustion of it was merely the separation of phlogiston. He even declared, that to make phosphorus, nothing more was necessary than to combine muriatic acid and phlogiston; and that this composition was as easily accomplished as that of sulphur itself‡.

† Ibid. 381.
‡ 27
Converted by combustion

‡ Three Hundred Experiments.

These assertions gained implicit credit; and the composition and nature of phosphorus were considered as completely understood, till Margraf of Berlin published his experiments in the year 1743. That great man, one of those illustrious philosophers who have contributed so much to the rapid increase of the science, distinguished equally for the ingenuity of his experiments and the clearness of his reasoning, attempted to produce phosphorus by combining together phlogiston and muriatic acid; but though he varied his process a thousand ways, presented the acid in many different states, and employed a variety of substances to furnish phlogiston, all his attempts failed, and he was obliged to give up the combination as impracticable. On examining the acid produced during the combustion of phosphorus, he found that its properties were very different from those of muriatic acid. It was therefore a distinct substance. The name of *phosphoric acid* was given to it; and it was concluded that phosphorus was composed of this acid united to phlogiston.

28
Into phosphoric acid.

But it was observed in 1772 by Morveau §, that phosphoric acid was heavier than the phosphorus from which it was produced (K); and Boyle had long before shewn that phosphorus would not burn except when in contact with air. These facts were sufficient to prove the inaccuracy of the theory concerning the composition of phosphorus; but they remained themselves unaccounted for, till Lavoisier published those celebrated experiments, which threw so much light on the nature and composition of acids.

§ Digress. Academ. P. 253.

He exhausted a glass globe of air by means of an air-pump;

E e

pump;

(G) Crell, in his life of Scheele, informs us that Scheele was himself the discoverer of the fact. This, he says, clearly appears from a printed letter of Scheele to Gahn, who was before looked upon as the discoverer. See *Crell's Annals*, English Transf. I. 17.

(H) Morveau, *Encycl. Method. Chimie*, art *Affinité*.—According to Nicholson at 160°. See his *Translation of Chaptal*.

(I) This acid shall be afterwards described.

(K) The same observation had been made by Margraf, but no attention was paid to it.

Phosphorus-pump; and after weighing it accurately, he filled it with oxygen gas, and introduced into it 100 grains of phosphorus. The globe was furnished with a stop-cock, by which oxygen gas could be admitted at pleasure. He set fire to the phosphorus by means of a burning-glass. The combustion was extremely rapid, accompanied by a bright flame and much heat. Large quantities of white flakes attached themselves to the inner surface of the globe, and rendered it opaque; and these at last became so abundant, that notwithstanding the constant supply of oxygen gas, the phosphorus was extinguished. The globe, after being allowed to cool, was again weighed before it was opened. The quantity of oxygen employed during the experiment was ascertained, and the phosphorus, which still remained unchanged, accurately weighed. The white flakes, which were nothing else than pure phosphoric acid, were found exactly equal to the weights of the phosphorus and oxygen, which had disappeared during the process. Phosphoric acid therefore must have been formed by the combination of these two bodies; for the absolute weight of all the substances together was the same before and after the process*. It is impossible then that phosphorus can be composed of phosphoric acid and phlogiston, as phosphorus itself enters into the composition of that acid (L).

29
Which is phosphorus combined with oxygen.
*Lavoisier's Chemistry, Part I. chap. v.

Thus the combustion of phosphorus, like that of sulphur, is nothing else than its combination with oxygen; for during the process no new substance appears except the acid, accompanied indeed with much heat and light.

30
Phosphorus combines with sulphur.

Phosphorus combines readily with sulphur, as Margraf discovered during his experiments on phosphorus. This combination was afterwards examined by Mr Pelletier. The two substances are capable of being mixed in different proportions. Seventy-two grains of phosphorus and nine of sulphur, when heated in about four ounces of water, melt with a gentle heat. The compound remains fluid till it be cooled down to 77°, and then becomes solid. These substances were combined in the same manner in the following proportions:

72 Phosphor.	}	congeals at 59°
18 Sulphur		
72 Phosphor.	}	at 50°
36 Sulphur		
72 Phosphor.	}	at 41°
72 Sulphur		
72 Phosphor.	}	at 99°
216 Sulphur		

Phosphorus and sulphur may be combined also by melting them together without any water; but the combination takes place so rapidly, that they are apt to rush out of the vessel if the heat be not exceedingly moderate †.

† Pelletier, Jour. de Phys. xxxv. 382.

Phosphorus is capable of combining also with many other bodies: the compounds produced are called phosphurets.

The affinities of phosphorus have not yet been ascertained.

Carbon.

SECT. III. Of Carbon.

If a piece of wood be put into a crucible, well covered with sand, and kept red hot for some time, it is converted into a black shining brittle substance, without either taste or smell, well known under the name of charcoal. This substance contains always mixed with it several earthy and saline particles. When freed from these impurities it is called carbon.

Charcoal is insoluble in water. It is not affected (provided that all air be excluded) by the most violent heat which can be applied, excepting only that it is rendered much harder.

31
Properties of carbon.

New-made charcoal absorbs moisture with avidity. When heated to a certain temperature, it absorbs air copiously. La Metherie plunged a piece of burning charcoal into mercury, in order to extinguish it, and introduced it immediately after into a glass vessel filled with common air. The charcoal absorbed four times its bulk of air. On plunging the charcoal in water, one-fifth of this air was disengaged. This air, on being examined, was found to contain a much smaller quantity of oxygen than atmospheric air does. He extinguished another piece of charcoal in the same manner, and then introduced it into a vessel filled with oxygen gas. The quantity of oxygen gas absorbed amounted to eight times the bulk of the charcoal; a fourth part of it was disengaged on plunging the charcoal into water*. It appears from the experiments of Sennebier, that charcoal when exposed to the atmosphere absorbs oxygen gas in preference to azot †, as the other portion of common air is called.

* Jour. de Phys. xxx. 329.
† Ann. de Chim. iv. 261.

When heated to the temperature of 370° ‡, it takes fire, and, provided it has been previously freed from the earths and salts which it generally contains, it burns without leaving any residuum. If this combustion be performed in close vessels filled with oxygen gas instead of common air, part of the charcoal and oxygen disappear, and in their room is found a particular gas exactly equal to them in weight. This gas has the properties of an acid, and is therefore called carbonic acid gas. Mr Lavoisier, to whom we are indebted for this discovery, ascertained, by a number of very accurate experiments, that this gas was composed of about 28 parts of carbon and 72 of oxygen ||.

‡ Morveau, Encycl. Method. art. Affinité.

Carbon is susceptible of crystallization. In that state it is called diamond. The figure of the diamond varies considerably; but most commonly it is a hexagonal prism terminated by a six-sided pyramid. When pure it is colourless and transparent. Its specific gravity is from 3,44 to 3,55. It is one of the hardest substances in nature; and as it is not affected by a considerable heat, it was for many ages considered as incombustible. Sir Isaac Newton, observing that combustibles refracted light more powerfully than other bodies, and that the diamond possessed this property in great perfection, suspected,

32
Converted into an acid.

|| Mem. Acad. 1781, p. 448.

33
Susceptible of crystallization.

(L) The quantity of phosphorus consumed was 45 grains.
The quantity of oxygen gas - - - 69,375

Weight of the phosphoric acid produced 114,375
Phosphoric acid therefore is composed of 100 parts phosphorus and 154 oxygen.

Carbon. peated, from that circumstance, that it was capable of combustion. This singular conjecture was verified in 1694 by the Florentine academicians, in the presence of Cosmo III. grand duke of Tuscany. By means of a burning-glass, they destroyed several diamonds. Francis I. emperor of Germany, afterwards witnessed the destruction of several more in the heat of a furnace. These experiments were repeated by Rouelle, Macquer, and D'Arcet; who proved that the diamond was not merely evaporated, but actually burnt, and that if air was excluded it underwent no change.

No attempt, however, was made to ascertain the product, till Lavoisier undertook a series of experiments for that purpose in 1772. He obtained *carbonic acid gas*. It might be concluded from these experiments, that the diamond contains carbon; but it was reserved for Mr Tennant to shew that it consisted entirely of that substance.

34 When it forms diamond. Into a tube of gold, having one end closed and a glass tube adapted to the other to collect the product, that gentleman put $2\frac{1}{2}$ grains of diamonds and a quarter of an ounce of nitre (M). This tube was heated slowly; the consequence of which was, that great part of the nitric acid passed off before the diamond took fire, and by that means almost the whole of the carbonic acid formed during the combustion of the diamond remained in the potass, for which it has a strong affinity. To ascertain the quantity of this carbonic acid, he dissolved the potass in water, and added to the solution another salt composed of muriatic acid and lime. Muriatic acid has a stronger affinity for potass than for lime; it therefore combines with the potass, and at the same time the lime and carbonic acid unite and fall to the bottom of the vessel, because they are nearly insoluble in water. He decanted off the liquor, and put the lime which contained the carbonic acid gas into a glass globe, having a tube annexed to it. This globe and tube he then filled with mercury, and inverted into a vessel containing the same fluid. The lime by that means occupied the very top of the tube. It now remained to separate the carbonic acid from the lime, which may be done by mixing it with any acid, as almost every other acid has a stronger affinity for lime than carbonic acid has. Accordingly on introducing muriatic acid, 10,3 ounce measures of carbonic acid gas, or nearly 9,166 grains, were separated. But, according to the experiments of Lavoisier, this gas is composed of 72 parts of oxygen and 28 of carbon; 9,166 grains, therefore contain 2,56 grains of carbon, which is almost precisely the weight of the diamond consumed. It follows, therefore, that it was composed of pure carbon*. The difficulty of burning the diamond is owing entirely to its hardness. Messrs Morveau and Tennant rendered common charcoal so hard by exposing it for some time to a violent fire in close vessels, that it lost much of its natural tendency to combustion, and endured even a red heat without catching fire †.

* Phil. Transf. 1797. P. 123.
† Encycl. Method. Chimie, art. Acier.

Charcoal possesses a number of singular properties,

which render it of considerable importance. It is incapable of putrefying or rotting like wood, and is not therefore liable to decay through age. This property has been long known. It was customary among the ancients to *char* the outside of those stakes which were to be driven into the ground or placed in water, in order to preserve the wood from spoiling. New-made charcoal, by being rolled up in cloths which have contracted a disagreeable odour, effectually destroys it. It takes away the bad taint from meat beginning to putrefy, by being boiled along with it. It is perhaps the best teeth powder known. Mr Lowitz of Petersburg has shewn, that it may be used with advantage to purify a great variety of substances.

Carbon unites with a number of bodies, and forms ³⁵ Carburets, with them compounds known by the name of *carburets*.

Its affinities have not yet been ascertained.

SECT. IV. Of Hydrogen.

Put into a glass vessel furnished with two mouths a quantity of fresh iron filings, quite free from rust. Lute ³⁶ Method of procuring hydrogen. into one of these mouths the end of a crooked glass tube. Insert the other end of this tube below a glass jar filled with water, and inverted into a pneumatic apparatus. Then pour upon the iron filings a quantity of sulphuric acid, diluted with twice its own weight of water, and close up the mouth of the vessel. Immediately the iron filings and acid effervesce with violence, a vast quantity of gas is produced, which rushes through the tube and fills the jar. This gas is called *hydrogen gas* (N).

It was obtained by Dr Mayow and by Dr Hales from various substances, and had been known long before in mines under the name of the *fire damp*. Mr Cavendish* was the first who examined its properties with attention. They were afterwards more fully investigated by Priestley, Scheele, and Fontana. * Phil. Transf. 1766.

Hydrogen, like *air*, is invisible and elastic, and capable of indefinite compression and dilatation. ³⁷ Its properties.

Its specific gravity differs according to its purity, Kirwan found it 0,00010 †; Lavoisier 0,000094 ‡, or about twelve times lighter than common air. † On Phlogiston Sect. 1st. ‡ Lavoisier's Chemistry, Appendix.

All burning substances are immediately extinguished by being plunged into this gas. It is incapable, therefore, of supporting combustion.

Animals, when they are obliged to breathe it, die almost instantaneously. Scheele, indeed, found that he could breathe it for some time without inconvenience §; § Scheele on Fire. but Fontana, who repeated the experiment, discovered that this was owing to the quantity of common air contained in the lungs when he began to breathe; for on expiring as strongly as possible before drawing in the hydrogen gas, he could only make three respirations, and even these produced extreme feebleness and oppression about the breast ||.

If a phial be filled with hydrogen gas, and a lighted candle be brought to its mouth, the gas will take fire, and burn gradually till it is all consumed. If hydrogen ^{|| Four de Phys. xv. 99.}

E c 2

gen

(M) Nitre is composed of potass and nitric acid; and nitric acid contains a great quantity of oxygen, which is easily separated by heat. Diamond, when mixed with nitre, burns at a much lower heat than by any other process.

(N) It was formerly called *inflammable air*, and by some chemists *phlogiston*.

Hydrogen. gen and oxygen gas be mixed together and kindled, they burn instantaneously, and produce an explosion like gunpowder. The same effect follows when a mixture of hydrogen gas and atmospheric air is kindled, but the explosion is less violent. Hydrogen gas will not burn except in contact with oxygen gas, nor will it burn even in contact with oxygen gas, unless a red heat be applied to it. If 85 parts by weight of oxygen gas, and 15 of hydrogen gas, be mixed together, and set on fire in a close vessel, they disappear, and in their place there is found a quantity of water exactly equal to them in weight. This water must be composed of these two gases; for it did not previously exist in the vessel, and no other substance except the gases was introduced. Water then is composed of oxygen and hydrogen; and the combustion of hydrogen is nothing else but the act of its combination with oxygen (o).

38
Composition of water.

It had been supposed, in consequence of the experiments of Dr Priestley and several other philosophers, that when hydrogen gas was allowed to remain in contact with water, it was gradually decomposed, and converted into another gas; but Mr de Morveau*, Mr Hassenfratz†, and Mr Libes‡, have shewn that it undergoes no change, provided sufficient care be taken to exclude every other gas.

* *En cycl. Method.*

C bim. i. 754.

† *Ann. de*

C bim. i. 192.

‡ *Jour. de*

Phys. xxxvi.

412.

39

Compounds

of hydro-

gen gas.

Hydrogen gas dissolves sulphur, phosphorus, and carbon. The compounds are called *sulphurated, phosphorated, and carbonated hydrogen gas.*

40

Sulphurated hydro-

gen gas.

1. Sulphurated hydrogen gas was first examined with attention by Scheele, who, together with Bergman, discovered many of its properties. Mr Kirwan likewise published a very valuable paper on the same subject. If equal parts of sulphur and potash be melted together in a covered crucible, they combine together, and form a compound known by the name of *sulphuret of potash*, but formerly called, from its red colour, *hepar sulphuris*, or *liver of sulphur*. When this substance is moistened with water, it gives out a quantity of sulphurated hydrogen gas; hence this gas was at first called *hepatic gas*.

Mr Gengembre enclosed a bit of sulphur in a glass vessel filled with hydrogen gas, and melted the sulphur by means of a burning-glass. A quantity of it disappeared, and the hydrogen assumed all the properties of *hepatic gas*. Hence it follows that this gas is merely sulphur dissolved in hydrogen gas.

The easiest method of obtaining it is to pour an acid, the muriatic for instance, on a quantity of the sulphuret reduced to powder. An effervescence takes place, the gas is extricated, and may be collected by means of a pneumatic apparatus. The theory of this emission is obvious. The sulphur is gradually converted into sulphuric acid, by decomposing the water, which is always united with acids, and seizing its oxygen: the hydrogen of the water is thus set at liberty; it assumes the gaseous form, and at the same time dissolves

part of the remaining sulphur, for which it has a considerable affinity. Hydrogen.

The specific gravity of sulphurated hydrogen gas is 0,00135*; it is to common air as 1106 to 1000.

* Kirwan on Phlogiston, sect. 111.

It has a very fetid odour, precisely similar to that emitted by rotten eggs, which indeed is owing to the emission of the very same gas.

It is not more respirable than hydrogen gas. When set on fire, in contact with oxygen gas, it burns with a light blue flame, without exploding, and at the same time a quantity of sulphur is deposited. The combustion of this gas, then, is merely the union of its hydrogen, and perhaps part of its sulphur, with oxygen.

This gas turns syrup of violets to a green colour†. † *Fourcroy's Chemistry, art. Sulphur*

It does not seem capable of existing in atmospheric air without decomposition; for the moment it comes into contact with oxygen gas, sulphur is deposited‡. ‡ *Bergman.*

2. Phosphorated hydrogen gas was discovered by Mr Gengembre in 1783, and by Mr Kirwan some time after, before he became acquainted with the experiments of that gentleman. It may be procured by mixing phosphorus with potash dissolved in water, and applying a boiling heat to the solution. The phosphorus is gradually converted into an acid by decomposing the water, and uniting with its oxygen. The hydrogen assumes the form of a gas, and flies off after dissolving a little of the phosphorus. This gas may be collected by means of a pneumatic apparatus.

41
Phosphorated hydrogen gas.

Phosphorated hydrogen gas has a smell resembling that of putrid fish. When mixed with oxygen gas or common air, it becomes luminous; and on the application of the smallest heat, it burns with astonishing rapidity§. The products are water and phosphoric acid. § *Kirwan.*

The combustion of this gas therefore is nothing else than the union of its phosphorus and hydrogen with oxygen, attended by an emission of heat and light. Phosphorated hydrogen gas may also be formed by introducing a bit of phosphorus into a jar containing hydrogen gas; but care must be taken to make this gas as dry as possible; for its affinity with phosphorus is weakened in proportion to its moisture||.

|| *Brugnatelli, Nicholson's Journal, i. 445.*

3. Carbonated hydrogen gas arises spontaneously in hot weather from marshes, but always mixed with several other gases. Several species of it have been lately discovered by the associated Dutch chemists Bondt, Dieman, Van Troostwyck, and Lauwerenberg¶. When ¶ *Ann. de Chim. xxi. 46.*

¶ *Ann. de Chim. xxi. 46.*

75 parts of sulphuric acid and 25 of spirit of wine are mixed together, a gas is extricated which suffers no alteration from standing over water. Its specific gravity is 0,00111, or it is to common air as 909 to 1000. It has a fetid odour, and burns with a strong compact flame. When passed through sulphur it is converted into sulphurated hydrogen gas, and at the same time a quantity of carbon is deposited in the form of a fine powder; it must therefore be composed of carbon and hydrogen gas. When burnt, the product is carbonic acid.

42
Carbonated hydrogen gas.

(o) The history of this great discovery, and the objections which have been made to it, we reserve for the chapter which treats of *Water*, where they will be better understood than they could be at present. This substance was called *hydrogen* by the French chemists, because it enters into the composition of water, from *ὕδωρ* *water*, and *γενναί* *I am born*. Objections have been made to the propriety of the name, into which we shall not enter. It ought never to be forgotten that Newton had long before, with a sagacity almost greater than human, conjectured, from its great refracting power, that water contained a combustible substance.

Part I.

Hydrogen. acid gas and water *. By making ether (P) pass thro' a red hot glass tube, another carbonated hydrogen gas was formed, the specific gravity of which was 0,00086. Spirit of wine, passed in the same manner, afforded a gas, the specific gravity of which was 0,00053, and which burned with a paler flame than the other two. These gases were found to contain from 80 to 74 parts of carbon, and from 20 to 26 of hydrogen. The first species was found to contain most carbon, and the last to contain least †.

† Ibid. The affinity of hydrogen gas for these three combustibles is as follows:

- Sulphur,
- Carbon,
- Phosphorus (Q).

Dr Austin found, that by repeatedly passing electric explosions through a small quantity of carbonated hydrogen gas, it was permanently dilated to more than twice its original bulk. He rightly concluded, that this remarkable expansion could only be owing to the evolution of hydrogen gas. On burning air thus expanded, he found that it required a greater quantity of oxygen than the same quantity of gas not dilated by electricity: An addition therefore had been made to the combustible matter; for the quantity of oxygen necessary to complete the combustion of any body, is always proportional to the quantity of that body. He concluded from these experiments, that he had decomposed the carbon which had been dissolved in the hydrogen gas; and that carbon was composed of hydrogen and azot (R), some of which was always found in the vessel after the dilated gas had been burnt by means of oxygen ‡. If this conclusion be fairly drawn, we must expunge carbon from the list of simple substances, and henceforth consider it as a compound.

§ Phil. Trans. lxxx. 51. There was one circumstance which ought to have prevented Dr Austin from drawing this conclusion, at least till warranted by more decisive experiments. The quantity of combustible matter had been increased. Now, if the expansion of the carbonated hydrogen gas was owing merely to the decomposition of carbon, no such increase ought to have taken place, but rather the contrary; for the carbon, which was itself a combustible substance, was resolved into two ingredients, hydrogen and azot, only the first of which burnt on the addition of oxygen and the application of heat. Dr Austin's experiments have been lately repeated by Mr William Henry with a great deal of accuracy §. He found that the dilatation which Dr Austin describes actually took place, but that it could not be carried beyond a certain degree, a little more than twice the original

bulk of the gas. Upon burning separately by means of oxygen, two equal portions of carbonated hydrogen gas, one of which had been expanded by electricity to double its original bulk, the other not, he found that each of them produced precisely the same quantity of carbonic acid gas. Both therefore contained the same quantity of carbon; consequently no carbon had been decomposed by the electric shocks.

Mr Henry then suspected that the dilatation was owing to the water which every gas contains in a larger or smaller quantity. To ascertain this, he endeavoured to deprive the carbonated hydrogen gas of as much water as possible, by making it pass over very dry potash, which attracts water with avidity. Gas treated in this manner could only be expanded one-sixth of its bulk; but on admitting a drop or two of water, the expansion went on as usual. The substance decomposed by the electricity, then, was not the carbon, but the water in the carbonated hydrogen gas. Nor is it difficult to see in what manner this decomposition is effected. Carbon, at a high temperature, has a greater affinity for oxygen than hydrogen has; for if the steam of water be made to pass over red hot charcoal, it is decomposed, and carbonic acid and hydrogen gas are formed. The electric explosion supplies the proper temperature; the carbon unites with the oxygen of the water, and forms carbonic acid; and the hydrogen, thus set at liberty, occasions the dilatation. Carbonic acid gas is absorbed with avidity by water: and when water was admitted into 700 measures of gas thus dilated, 100 measures were absorbed; a proof that carbonic acid gas was actually present. As to the azot which Dr Austin found in his dilated gas, it evidently proceeded from the admission of some atmospheric air, about 73 parts of which in the 100 consist of this gas: for Dr Austin's gas had stood long over water; and Drs Priestley and Higgins have shewn that air in such a situation always becomes impregnated with azot.

The affinities of hydrogen have not yet been ascertained, but perhaps they are as follows:

- Oxygen,
- Carbon,
- Azot.

SECT. V. Of Azot.

If a quantity of iron filings and sulphur, mixed together and moistened with water, be put into a glass vessel full of air, it will absorb all the oxygen in the course of a few days; but a considerable residuum of air still remains incapable of any farther diminution. This residuum has obtained the appellation of azotic gas.

It

(P) Ether is a very volatile and fragrant liquid, obtained by mixing spirit of wine and acids, and distilling. It shall be afterwards described.

(Q) Sulphur decomposes carbonated hydrogen gas; therefore its affinity is greater than that of carbon. The Dutch chemists melted phosphorus in carbonated hydrogen gas, but no change was produced; therefore the affinity of phosphorus is inferior to that of carbon.

(R) See next Section.—His theory was, that carbonated hydrogen gas was composed of hydrogen, and azot, and carbon of azot, and carbonated hydrogen gas, which comes nearly to the same thing with regard to the elements of carbon. It is singular enough, that though Dr Austin would not allow the presence of carbon in carbonated hydrogen gas, he actually decomposed it by melting sulphur in it: the sulphur combined with the hydrogen gas, and a quantity of carbon was precipitated. This experiment he relates without making any remarks upon it, and seems indeed not to have paid any attention to it.

Azot.

And found unsuccess-ful.

Affinities of hydrogen.

Method of procuring azot.

† Ibid.

‡ Ibid.

§ Phil.

Trans. lxxx.

51.

Examined,

part 2d.

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^{Azot.}
It was discovered in 1772 by Dr Rutherford, now professor of botany in the university of Edinburgh (s). Scheele procured it by the above process as early as 1776, and proved that it was a distinct fluid. Mr Lavoisier afterwards proved the same thing, without any previous knowledge of Scheele's discoveries.

The air of the atmosphere contains about $\frac{73}{100}$ parts of azotic gas; almost all the rest is oxygen gas. The easiest method of procuring azotic gas is to put some sulphuret of potash into a glass vessel filled with air, and accurately closed, and then to apply heat to the sulphuret. All the oxygen is absorbed almost instantly. This method was first pointed out by Morveau*.

Mr Kirwan examined the specific gravity of azotic gas obtained by Scheele's process; it was 0,00120: it is therefore somewhat lighter than the atmospheric air; it is to atmospheric air as 985 to 1000†.

It tinges delicate blue colours slightly with green‡. It is exceedingly noxious to animals; if they are obliged to respire it, they drop down dead almost instantly (†). No combustible will burn in it. This is the reason that a candle is extinguished in atmospherical air as soon as the oxygen near it is consumed. Mr Goettling, indeed, published, in 1794, that phosphorus shone, and was converted into phosphoric acid, in pure azotic gas. Were this the case, it would not be true that no combustible burns in this gas; for the conversion of phosphorus into an acid, and even its shining, is an actual though slow combustion. Mr Goettling's experiments were soon after repeated by Drs Scherer and Jaeger, who found that phosphorus does not shine in azotic gas when it is perfectly pure; and that therefore the gas on which Mr Goettling's experiments were made had contained a mixture of oxygen gas, owing principally to its having been only confined by water. These results were afterwards confirmed by Professor Lampadius and Professor Hildebrandt. It is therefore proved beyond a doubt, that phosphorus does not burn in azotic gas, and that whenever it appears to do so, there is always some oxygen gas present §.

Azotic gas is capable of dissolving phosphorus, as has been proved by the experiments of Fourcroy and Vaquelin.

It dissolves also a little carbon: for azotic gas obtained from animal substances, which contain a great deal of azot, when confined long in jars, deposits on the

sides of them a black matter which has the properties of carbon*.

These two solutions, the properties of which have not yet been accurately examined, are called *phosphorated and carbonated azotic gas*.

Azotic gas is capable of combustion. Take a glass tube, the diameter of which is about the sixth part of an inch; shut one of its ends with a cork, through the middle of which passes a small wire with a ball of metal at each end. Fill the tube with mercury, and then plunge its open end into a basin of that fluid. Throw up into the tube as much of a mixture, composed of 13 parts of azotic and 87 parts of oxygen gas, as will fill 3 inches. Through this gas make, by means of the wire in the cork, a number of electric explosions pass. The volume of gas gradually diminishes, and in its place there is found a quantity of *nitrous acid*. This acid, therefore, is composed of azot and oxygen: and these two substances are capable of combining, or, which is the same thing, azotic gas is capable of combustion in the temperature produced by electricity, which we know to be pretty high. The combustibility of azotic gas, and the nature of the product, was first discovered by Mr Cavendish, and communicated to the Royal Society on the 2d of June 1785 (u).

The affinities of azot are still unknown. It has never yet been decomposed, and must therefore, in the present state of our knowledge, be considered as a simple substance. Dr Priestley, who obtained azotic gas at a very early period of his experiments, considered it as a compound of oxygen gas and phlogiston, and for that reason gave it the name of *phlogisticated air*. According to the theory of Stahl, which was then universally prevalent, he considered combustion as merely the separation of phlogiston from the burning body. To this theory he made the following addition: Phlogiston is separated during combustion by means of chemical affinity: *Air* (that is, *oxygen gas*) has a strong affinity for phlogiston: Its presence is necessary during combustion, because it combines with the phlogiston as it separates from the combustible; and it even contributes by its affinity to produce that separation: The moment the air has combined with as much phlogiston as it can receive, or, to use a chemical term, the moment it is *saturated* with phlogiston, combustion necessarily stops, because no more phlogiston can leave the combustion.

(s) See his thesis *De Aere Mephitico*, published in 1772.—“Sed aer salubris et purus respiracione animali non modo ex parte fit mephiticus sed et *aliam indolis suæ mutationem inde patitur*. Postquam enim omnis aer mephiticus (carbonic acid gas) ex eo, ope lixivii caustici secretus et abductus fuerit, *qui tamen restat* nullo modo salubrior inde evadit; nam quamvis nullam ex aqua calcis præcipitationem faciat haud minus quam antea *et flammam et vitam extinguit*. Page 17.

“Aer qui per carbones ignitos folle adactus fuit, atque deinde ab omni aere mephitico (*carbonic acid gas*) expurgatus, malignus tamen adhuc reperitur et omnino similis est ei qui respiracione inquinatur. Immo ab experimentis patet hanc solam esse aeris mutationem quæ inflammationi adscribi potest. Si enim accenditur materies quælibet quæ ex phlogisto et basi fixa atque simplici constat, *aer inde natus ne minimam aeris mephitici quantitatem in se continere videtur*. Sic aer in quo sulphur aut phosphorus urinx combustus fuit, licet maxime malignus, calcem tamen ex aqua minime præcipitat. Interdum quidem si ex phosphoro natus fuerit, nubeculam aquæ calcis inducit sed tenuissimam, nec aeri mephitico attribuendam, sed potius acido illi quod in phosphoro inest, et quod, ut experimenta docuerunt, hoc singulari dote pollet.” Page 19.

(†) Hence the name *azot*, given it by the French chemists, which signifies *destructive to life*, from *a* and *ζωη*.

(u) It is remarkable enough, that the acidity of nitric acid was ascribed by Mayow, in 1674, to the presence of oxygen. *Indoles caustica spiritus nitri* (says he) *a particulis ejus igneo-aereis provenit*. Tract. p. 19.

^{Azot.}
Discovery of azot.

* Nicol-
son's Jour-
nal, i. 268.

† On Phlo-
giston § 1st.

‡ Its proper-
ties

§ Fourcroy,
Ann. de
Chim. i. 45.

¶ Nicol-
son's
Journal, ii.
8.

^{Azot.}
* Fourcroy,
Ann. de
Chim. i. 45.

⁵¹
Production
of nitric
acid.

⁵²
Attempts
to decom-
pose azot

^{Azot.} combustibile (v) : Air saturated with phlogiston is azotic gas. This was a very ingenious theory, and, when Dr Priestley published it, exceedingly plausible. A great number of the most eminent chemists accordingly embraced it: But it was soon after discovered, that during combustion the quantity of air, instead of increasing, as it ought to have done, had phlogiston been added to it, actually diminished both in volume and weight. There was no proof, therefore, that during combustion any substance whatever combined with air, but rather the contrary. It was discovered also, that a quantity of air combined with the burning substance during combustion, as we have seen was the case with sulphur, phosphorus, carbon, and hydrogen; and that this air had the properties of oxygen gas. These discoveries entirely overthrew the evidence on which Dr Priestley's theory was founded: accordingly, as no attempt to decompose azot has succeeded, it has been given up by almost every chemist except Dr Priestley himself. Atmospheric air, as Scheele first proved, is composed of about 27 parts of oxygen and 73 of azotic gas. During combustion, the oxygen is abstracted and the azotic gas remains behind.

⁵³
Unsuccessful

La Metherie made an attempt to prove that azot was composed of oxygen and carbon (w). He took a bit of burning charcoal, extinguished it in mercury, and then plunged it while hot into oxygen gas. On being plunged into water, one fourth of the gas was disengaged, and part of it was found to consist of azotic gas. From this he concluded that he had formed azotic gas by combining oxygen and carbon: But it was proved by Mr Lavoisier, beyond the possibility of doubt, that oxygen and carbon form carbonic acid gas. They cannot then certainly form azot; for two contradictory facts cannot both be true. There must then have been something overlooked in the experiment. Indeed the experiment itself does not warrant the conclusion which De La Metherie drew from it. He did not ascertain whether the weight of the charcoal was diminished; and, besides, there was azot mixed with the oxygen gas which he employed, as he himself has informed us: And how was it possible for him to admit the charcoal into water without, at the same time, admitting some atmospherical air?

We have now described all the combustibles which are at present reckoned simple, except the metals. We have found, that during combustion all of them combine with oxygen; that no part of them is disengaged, no part of them lost: we have therefore concluded, that the combustion of these substances is nothing else but the act of their uniting with oxygen. We have seen, however, that none of them, except phosphorus, was capable of uniting with oxygen at the common temperature of the atmosphere; that, in order to produce the union, heat was necessary, and that the degree of this heat was different for each. Hydrogen required a red heat, and azot a still greater. We have seen,

too, that during these combinations a quantity of heat and light escaped. Now, why is heat necessary for these combinations? and whence come the heat and the light which we perceive during the combustion of these bodies? These questions are of the highest importance, and can only be answered by a particular investigation of the nature and properties of heat and light. This investigation we shall attempt, as soon as we have described the *metals* and *earths*, which form the subject of the two following chapters.

^{Metals.}

CHAP. III. Of METALS.

METALS may be considered as the great instruments ⁵⁴ Properties of metals. of all our improvements: Without them, many of the arts and sciences could hardly have existed. So sensible were the ancients of their great importance, that they raised those persons who first discovered the art of working them to the rank of deities. In chemistry, they have always filled a conspicuous station: at one period the whole science was confined to them; and it may be said to have owed its very existence to a rage for making and transmuting metals.

1. One of the most conspicuous properties of the metals is a particular brilliancy which they possess, and which has been called the *metallic lustre*. This proceeds from their reflecting much more light than any other body; a property which seems to depend partly on the closeness of their texture. This renders them peculiarly proper for mirrors, of which they always form the basis.

⁵⁵
Lustre.

2. They are absolutely opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for instance, $\frac{1}{80000}$ of an inch thick, does not permit the smallest ray of light to pass through it. Gold, however, may be rendered transparent; for gold leaf, $\frac{1}{80000}$ of an inch thick, transmits light of a lively green colour*. And it is not improbable that all the other metals, as Sir Isaac Newton ⁵⁶ Opacity. supposed, would become transparent, if they could be reduced to a sufficient degree of thinness. It is to this opacity that a part of the excellence of the metals, as mirrors, is owing; their brilliancy alone would not qualify them for that purpose.

3. They may be melted by the application of heat, and even then still retain their opacity. This property enables us to cast them in moulds, and then to give them any shape we please. In this manner many elegant iron utensils are formed.

⁵⁷
Fusibility.

4. Their specific gravity is greater than that of any other body hitherto discovered.

⁵⁸
Gravity.

5. They are better conductors of electricity than any other body.

6. But one of their most important properties is *Malleability*; by which is meant the capacity of being ⁵⁹ extended and flattened when struck with a hammer. This property enables us to give the metallic body any form we think proper, and thus renders it easy for us

to

(v) This ingenious theory was first conceived by Dr Rutherford, as appears from the following passage of his thesis. "Ex iisdem etiam deducere licet quod aer ille malignus (azotic gas) componitur ex aere atmospherico cum phlogisto unito et quasi saturato. Atque idem confirmatur eo, quod aer qui metallorum calcinationi jam inservit, et phlogiston ab iis abripuit, ejusdem plane sit indolis." *De aere Mephitico*, p. 20.

(w) Or rather of *hydrogen*, for he considered carbon itself as a compound.

Metals. to convert them into the various instruments for which we have occasion. All metals do not possess this property; but it is remarkable that almost all those which were known to the ancients have it. Heat increases this property considerably.

60 Ductility. 7. Another property which is also wanting in many of the metals, is *ductility*; by which we mean the capacity of being drawn out into wire by being forced through holes of various diameters. This property has by some been called *tenacity*; and it doubtless depends upon the tenacity of the various metals.

61 Calcination 8. When exposed to the action of heat and air, most of the metals lose their lustre, and are converted into earthy-like powders of different colours and properties, according to the metal and the degree of heat employed. Several of the metals even take fire when exposed to a strong enough heat; and after combustion the residuum is found to be the very same earthy-like substance. If any of these *calces*, as they are called, be mixed with charcoal-powder, and exposed to a strong heat in a proper vessel, it is changed again to the metal from which it was produced. From these phenomena Stahl concluded, that metals were composed of *earth* and *phlogiston*. He was of opinion that there was only one primitive earth, which not only formed the basis of all those substances known by the name of earths, but the basis also of all the metals. He found, however, that it was impossible to combine any mere earth with phlogiston; and concluded, therefore, with Beccher, that there was another principle besides earth and phlogiston, which entered into the composition of the metals. To this principle Beccher gave the name of *mercurial earth*, because, according to him, it existed most abundantly in *mercury*. This principle was supposed to be very volatile, and therefore to fly off during calcination: and some chemists even affirmed that it might be obtained in the foot of those chimneys under which metals have been calcined.

63 Defective. A striking defect was soon perceived in this theory. The original metal may again be produced by heating its calx along with some other substance which contains phlogiston: now, if the mercurial earth flies off during combustion, it cannot be necessary for the formation of complete metals, for they may be produced without it: if, on the contrary, it adheres always to the calx, there is no proof of its existence at all. Chemists, in consequence of these observations, found themselves obliged to discard the mercurial principle altogether, and to conclude that metals were composed of earth only, united to phlogiston. But if this be really the case, how comes it that these two substances cannot be united by art? Henkel was the first who attempted to solve this difficulty. According to him, earth and phlogiston are substances of so opposite a nature, that it is exceedingly difficult, or rather it has been hitherto impossible, for us to commence their union; but after it has been once begun by nature, it is an easy matter to complete it. No calcination has hitherto deprived the metals of all their phlogiston; some still adheres to the calces. It is this remainder of phlogiston which renders it so easy to restore them to their metallic state.

64 Improved by Henkel.

Were the calcination to be continued long enough to deprive them altogether of phlogiston, they would be reduced to the state of other earths; and then it would be equally difficult to convert them into metals, or, to use a chemical term, to *reduce* them. Accordingly we find that the more completely a calx has been calcined, the more difficult is its reduction. This explanation was favourably received. But after the characteristic properties of the various *earths* had been ascertained, and the calces of metals were accurately examined, it was perceived that the calces differed in many particulars from all the *earths*, and from one another. To call them all the same substance, then, was to go much farther than either experiment or observation would warrant, or, rather, it was to declare open war against both experiment and observation. It was concluded, therefore, that each of the metals was composed of a peculiar *earthy substance* combined with phlogiston. For this great improvement in accuracy, chemistry is chiefly indebted to Bergman.

But there were several phenomena of calcination which had all this time been unaccountably overlooked. The calces are all considerably heavier than the metals from which they are obtained. Boyle had observed this circumstance, and had ascribed it to a quantity of *fire* which, according to him, became fixed in the metal during the process*. But succeeding chemists paid little attention to it, or to the action of air, till Mr Lavoisier published his celebrated experiments on calcination, in the Memoirs of the Paris Academy for 1774. He put eight ounces of *tin* into a large glass retort, the point of which was drawn out into a very slender tube to admit of easy fusion. This retort was heated slowly till the tin began to melt, and then sealed hermetically. This heat was applied to expel some of the air from the retort; without which precaution it would have expanded and burst the vessel. The retort, which was capable of containing 250 cubic inches, was then weighed accurately, and placed again upon the fire. The tin soon melted, and a pellicle formed on its top, which was gradually converted into a grey powder, that sunk by a little agitation to the bottom of the liquid metal: in short, the tin was partly converted into a *calx*. This process went on for three hours; after which the calcination stopped, and no farther change could be produced on the metal. The retort was then taken from the fire, and found to be precisely of the same weight as before the operation. It is evident, then, that no new substance had been introduced, and that therefore the increased weight of calces cannot, as Boyle supposed, be owing to the fixation of fire (x).

When the point of the retort was broken, the air rushed in with a hissing noise, and the weight of the retort was increased by ten grains. Ten grains of air, therefore, must have entered, and, consequently, precisely that quantity must have disappeared during the calcination. The metal and its calx being weighed, were found just ten grains heavier than before: therefore, the air which disappeared was absorbed by the metal: and as that part of the tin which remained in a metallic state was unchanged, it is evident that this

Metals.

65 Further improved.

66 Still imperfect.

* *Fire and flame weighed.*

67 Refuted by Lavoisier.

(x) This experiment had been performed by Boyle with the same success. He had drawn a wrong conclusion from not attending to the state of the air of the vessel. *Shaw's Boyle*, II. 394.

air must have united with the calx. The increase of weight, then, which metals experience during calcination, is owing to their uniting with air (y). But all the air in the vessel was not absorbed, and yet the calcination would not go on. It is not the whole, then, but some particular part of the air which unites with the calces of metals. By the subsequent discoveries of Priestley, Scheele, and Lavoisier himself, it was ascertained, that the residuum of the air, after calcination has been performed in it, is always pure azotic gas: It follows, therefore, that it is only the oxygen which combines with calces; and that a metallic calx is not a simple substance, but a compound. Mr Lavoisier observed, that the weight of the calx was always equal to that of the metal employed, together with that of the oxygen absorbed. It became a question then, Whether metals, during calcination, lost any substance, and consequently, whether they contained any phlogiston? Mr Lavoisier accordingly proposed this question; and he answered it himself by a number of accurate experiments and ingenious observations. Metals cannot be calcined excepting in contact with oxygen, and in proportion as they combine with it. Consequently they not only absorb oxygen during their calcination, but that absorption is absolutely necessary to their assuming the form of a calx. If the calx of mercury be heated in a retort, to which a pneumatic apparatus is attached, to the temperature of 1200°, it is converted into pure mercury; and, at the same time, a quantity of oxygen separates from it in a gaseous form. As this process was performed in a close vessel, no new substance could enter: The calx of mercury, then, was reduced to a metallic state without phlogiston. The weights of the metal and the oxygen gas are together just equal to that of the calx; the calx of mercury, therefore, must be composed of mercury and oxygen; consequently there is no reason whatever to suppose that mercury contains phlogiston. Its calcination is merely the act of uniting it with oxygen (z). The calces of lead, silver, and gold, may be decomposed exactly in the same manner; and Mr Van Marum, by means of his great electrical machine, decomposed also those of tin, zinc, and antimony, and resolved them into their respective metals and oxygen*. The same conclusions, therefore, must be drawn with respect to these metals. All the metallic calces may be decomposed by presenting to

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them substances which have a greater affinity for oxygen than they have. This is the reason that charcoal-powder is so efficacious in reducing them: and if they are mixed with it, and heated in a proper vessel, furnished with a pneumatic apparatus, it will be easy to discover what passes. During the reduction, a great deal of carbonic acid gas comes over, which, together with the metal, is equal to the weight of the calx and the charcoal: it must therefore contain all the ingredients; and we know that carbonic acid gas is composed of carbon and oxygen. During the process, then, the oxygen of the calx combined with charcoal and the metal remained behind. It cannot be doubted, therefore, that all the metallic calces are composed of the entire metals combined with oxygen; and that calcination, like combustion, is merely the act of this combination. All metals, then, in the present state of chemistry, must be considered as simple substances; for they have never yet been decomposed.

The words *calx* and *calcination* are evidently improper, as they convey false ideas; we shall therefore afterwards employ, instead of them, the words *oxide* and *oxidation*, which were invented by the French chemists. A metallic *oxide* signifies a metal united with oxygen; and *oxidation* implies the act of that union.

Metals are capable of uniting with oxygen in different proportions, and, consequently, of forming each of them different oxides. These are distinguished from one another by their colour. One of the oxides of iron, for instance, is of a green colour; it is therefore called the *green oxide*; the other, which is brown, is called the *brown oxide*.

The metals at present amount to 21; only 11 of which were known before the year 1730. Their names are gold, silver, platinum, mercury, copper, iron, tin, lead, zinc, antimony, bismuth, arsenic, cobalt, nickel, manganese, tungsten, molybdenum, uranium, tellurium, titanium, chromium.

The first eight of these were formerly called *metals* by way of eminence, because they are possessed either of malleability or ductility, or of both properties together; the rest were called *semimetals*, because they are brittle. But this distinction is now pretty generally laid aside; and, as Bergman observes, it ought to be so altogether, as it is founded on a false hypothesis, and conveys very erroneous ideas to the mind. The first

Ff four

(y) It is remarkable that John Rey, a physician of Perigord, had ascribed it to this very cause as far back as the year 1630: But his writings had excited little attention, and had sunk into oblivion, till after his opinion had been incontestibly proved by Lavoisier. Mayow also, in the year 1674, ascribed the increase of weight to the combination of metals with oxygen. *Quippe vix concipi potest (says he), unde augmentum illud antimonii (calcinati) nisi a particulis nitro-aereis igneisque inter calcinandum fixis procedat.* Tract. p. 28. *Plane ut antimonii fixatio non tam a sulphuris ejus externi assumptione, quam particulis nitro-aereis, quibus flamma nitri abundat ei infixis provenire videatur.* Ibid. p. 29.

(z) This experiment was performed by Mr Bayen in 1774. This philosopher perceived, earlier than Lavoisier, that all metals did not contain phlogiston. "Ces experiences (says he) vont nous detromper. Je ne tiendrai plus le langage des disciples de Stahl, qui seront forcés de restreindre la doctrine sur le phlogistique, ou d'avouer que les precipités mercuriels, dont je parle, ne sont pas des chaux metalliques, ou enfin qu'il y a des chaux qui peuvent se reduire sans le concours du phlogistique. Les experiences que j'ai faites me force de conclure que dans la chaux mercuriale dont je parle, le mercure doit son etat calcaire, non à la perte du phlogistique qu'il n'a pas effuyée, mais à sa combinaison intime avec le fluide elastique, dont le poids ajouté à celui du mercure est la seconde cause de l'augmentation de pesanteur qu'on observe dans les precipités que j'ai soumis à l'examen." *Jour. de Phys.* 1774, pages 288, 295. It was in consequence of hearing Bayen's paper read that Lavoisier was induced to turn his attention to the subject.

Gold. four metals were formerly called *noble* or *perfect metals*, because their oxides are reducible by the mere application of heat; the next four were *imperfect metals*, because their oxides were thought not reducible without the addition of some combustible substance; but this distinction also is now very properly exploded.

SECT. I. *Of Gold.*

⁷⁰
Properties
of gold.

GOLD seems to have been known from the very beginning of the world. Its properties and its scarcity have rendered it more valuable than any other metal.

It is of an orange red, or reddish yellow colour, and has no perceptible taste or smell.

No other substance can be compared with it in ductility and malleability. It may be beaten out into leaves so thin that one grain of gold will cover $56\frac{1}{2}$ square inches. These leaves are only $\frac{1}{81000}$ of an inch thick. But the gold leaf with which silver wire is covered has only $\frac{1}{2}$ of that thickness. An ounce of gold, upon silver wire, is capable of being extended more than 1300 miles in length.

Its tenacity is such, that a gold wire $\frac{1}{10}$ of an inch in diameter is capable of supporting a weight of 500

* *Macquer's* pounds without breaking*.
Diſſ.

Its hardness is 6 (A); its specific gravity 19.3. It melts at 32° of Wedgewood's pyrometer (B). When melted, it assumes a bright bluish green colour. It expands in the act of fusion, and consequently contracts while becoming solid more than most metals; a circumstance which renders it less proper for casting into moulds.

It requires a very violent heat to volatilize it; it is therefore, to use a chemical term, exceedingly *fixed*. Boyle and Kunkel kept it for some months in a glass-house furnace, and yet it underwent no change: nor did it lose any perceptible weight, after being exposed

† *Kirwan's* for some hours to the utmost heat of Mr Parker's lens †.
Miner. i. 92.

Mr Lavoisier, however, observed, that a piece of silver, which produces a much greater heat than common air, was sensibly *gilt*: Part of the metal, then, must have been volatilized.

After fusion, it is capable of assuming a crystalline form. Tillet and Mongez obtained it in short quadrangular pyramidal crystals.

⁷¹
Oxidation
of gold.

It is capable of combining with oxygen, and forming an *oxide of gold*. There are two methods of producing this combination, *the application of heat*, and *solution in acids*. When it is exposed to a very violent heat

in contact with air, gold absorbs oxygen. But the temperature must be very high; so high, indeed, that hardly any certain method of oxidating gold by heat is known, except by electricity. When the electric explosion is transmitted through gold leaf placed between two plates of glass, or when a strong charge is made to fall on a gilded surface—in both cases the metal is oxidated, and assumes a purple colour. It has been said also, that the same effect has been produced by a very violent fire; but few of the instances which have been adduced are well authenticated.

The other method of oxidating gold is much easier. For this purpose, equal parts of nitric and muriatic acids are mixed together (c) and poured upon gold; an effervescence takes place, the gold is gradually dissolved, and the liquid assumes a yellow colour. It is easy to see in what manner this solution is produced. No metal is soluble in acids till it has been reduced to the state of an oxide. There is a strong affinity between the oxide of gold and muriatic acid. The nitric acid furnishes oxygen to the gold, and the muriatic acid dissolves the oxide as it forms. When nitric acid is deprived of the greater part of its oxygen, it assumes a gaseous form, and is then called *nitrous gas*. It is the emission of this gas which causes the effervescence. The oxide of gold may be precipitated from the nitro-muriatic acid by pouring in a little potash dissolved in water, or, which is much better, a little lime; both of which have a stronger affinity for muriatic acid than the oxide has. This oxide is of a yellow colour.

It is probable that gold is capable of two different degrees of oxidation, and of forming two different oxides, *the yellow* and *the purple*: But neither the quantity of oxygen contained in these oxides, nor the differences between them, have been accurately ascertained. The oxides of gold may be decomposed in close vessels by the application of heat. The gold remains fixed, and the oxygen assumes the gaseous form. They may be decomposed, too, by all the substances which have a stronger affinity with oxygen than gold has. The affinities of the oxides of gold, according to Bergman*, * *Bergman*
on Electric
Attractions,
Opusc. t. 3. are as follows:

Muriatic acid,
Nitro-muriatic,
Nitric,
Sulphuric,
Arsenic,
Fluoric,

Tartarous,

(A) We have borrowed from Mr Kirwan the method of denoting the different degrees of hardness by figures, which we think a great improvement. These figures will be understood by Mr Kirwan's own explanation, which we here subjoin.

- 3, Denotes the hardness of chalk.
- 4, A superior hardness, but yet what yields to the nail.
- 5, What will not yield to the nail, but easily, and without grittiness, to the knife.
- 6, That which yields more difficultly to the knife.
- 7, That which scarcely yields to the knife.
- 8, That which cannot be scraped by a knife, but does not give fire with steel.
- 9, That which gives a few feeble sparks with steel.
- 10, That which gives plentiful lively sparks. *Kirwan's Mineralogy, I. 38.*

(B) According to the calculation of the Dijon academicians, it melts at 1298° Fahr.; according to Bergman, at 1301°.

(C) This mixture, from its property of dissolving gold, was formerly called *aqua regia* (for gold, among the alchemists, was the king of metals); it is now called *nitro-muriatic acid*.

Silver.

Tartarous,
Phosphoric,
Sebacic,
Pruffic,
Fixed alkali (D),
Ammonia.

proved that it may be volatilized, but that it requires a very violent heat.

Silver.

Gold is not changed either by air or water. It does not seem capable of combining either with sulphur or carbon. Mr Pelletier combined it with phosphorus, by melting together in a crucible half an ounce of gold and an ounce of phosphoric glass (E), surrounded with charcoal. The *phosphuret of gold* thus produced was brittle, whiter than gold, and had a crystallized appearance. It was composed of 23 parts of gold and one of phosphorus*. He formed the same compound by dropping small pieces of phosphorus into gold in fusion †.

72
Phosphuret
of gold.* Ann. de
Chim. i. 71.
† Ibid. xiii.
104.

Gold is also capable of combining with most of the metals. Its affinities are placed, by Bergman, in the following order:

Mercury,
Copper,
Silver,
Lead,
Bismuth,
Tin,
Antimony,
Iron,
Platinum,
Zinc,
Nickel,
Arsenic,
Cobalt,
Manganese,
Phosphorus?
Sulphurets of alkalies.

SECT. II. *Of Silver.*73
Properties
of silver.

SILVER appears to have been known almost as early as gold. It is a metal of a shining white colour, without either taste or smell.

It is the most malleable and ductile of all metals except gold, and perhaps platinum. It can be reduced to leaves about $\frac{1}{80000}$ of an inch thick, and drawn into wire much finer than a human hair.

Its tenacity is such, that a wire of silver, $\frac{1}{15}$ th of an inch in diameter, is capable of sustaining 270 pounds without breaking †.

‡ Macquer's
Diſſ.§ Kirwan.
|| Briffon.

Its hardness is 6,5 ϕ . Its specific gravity, before hammering, is 10,474; after hammering, 10,510 ||: for it is remarkable that the specific gravity of almost all the metals is increased by hammering.

It continues melted at 28° Wedgewood (F), but requires a greater heat to bring it to fusion ¶.

¶ Kirwan's
Mineral. ii.
107.

The experiments of the French academicians have

When cooled slowly, it assumes a crystalline form. Tillet and Mongez obtained it in quadrangular pyramidal crystals, both insulated and in groups.

Silver may be combined with oxygen, and converted into an oxide by exposure to a very violent heat. By this method Junker partly converted it into a *glass*; and Macquer, by exposing it 20 times successively to the heat of a porcelain furnace, obtained a *glass* (G) of an olive green colour*. The oxide of silver may also be formed by dissolving the metal in an acid, and precipitating it from its solution by potash, lime, &c.: for, during its solution, the metal becomes oxidated. Little is known at present concerning the oxides of silver, nor whether there be more than two, the *black* and the *blue*. From the experiments of Wenzel and Bergman, it follows, that one oxide of silver is composed of about 90 parts of metal and 10 of oxygen †. The affinities of the oxides, according to Bergman, are as follows:

Muriatic acid,
Sebacic,
Oxalic,
Sulphuric,
Saccholarctic,
Phosphoric,
Sulphurous,
Nitric,
Arsenic,
Fluoric,
Tartaric,
Citric,
Formic,
Lactic,
Acetous,
Succinic,
Pruffic,
Carbonic,
Ammonia.

74

Oxides of
silver.* Macquer's
Diſſ.† Kirwan's
Miner. ii.

493.

When silver is melted with sulphur in a low red heat, it combines with it and forms *sulphuret of silver*. It is very difficult to determine the proportion of the ingredients which enter into the composition of this substance, because there is an affinity between silver and its sulphuret, which disposes them to combine together.

The greatest quantity of sulphur which a given quantity of silver is capable of taking up is, according to Wenzel, $\frac{1}{100}$ †. Sulphuret of silver is of a black or very deep violet colour, brittle, and much more fusible than silver. If sufficient heat be applied, the sulphur is volatilized, and the metal remains behind in a state of purity.

If one ounce of silver, one ounce of phosphoric glass, and two drams of charcoal, be mixed together, and heated in a crucible, *phosphuret of silver* is formed. It

F f 2

is

(D) Have the alkalies any affinity for the yellow oxide? Is not their affinity confined to the purple oxide alone? And does not this oxide act as an acid?

(E) Phosphoric acid evaporated to dryness, and then fused.

(F) According to the Dijon academicians, it melts at 1044° Fahr.; according to Bergman, at 1000°.

(G) Metallic oxides, after fusion, are called *glasses*, because they acquire a good deal of resemblance, in some particulars, to common glasses.

Silver. is of a white colour, and appears granulated, or as it were crystallized. It breaks under the hammer, but may be cut with a knife. It is composed of four parts of silver and one of phosphorus. Heat decomposes it by separating the phosphorus*. Pelletier has observed, that silver in fusion is capable of combining with more phosphorus than solid silver: for when phosphuret of silver is formed by projecting phosphorus into melted silver, after the crucible is taken from the fire a quantity of phosphorus is emitted the moment the metal congeals †.

* Pelletier, *Ann. de Chim. i.* 73.

† *Ibid.* xliii. 110.

77
Alloys of silver.

Silver does not seem capable of combining with carbon.

Silver is capable of combining with gold, and forming an alloy (H) composed of one part of silver and five of gold. That this is the proportion of the ingredients, was discovered by Homberg. He kept equal parts of gold and silver in gentle fusion for a quarter of an hour, and found, on breaking the crucible, two masses; the uppermost of which was pure silver, the undermost the whole gold combined with $\frac{1}{5}$ th of silver. Silver, however, may be mixed with gold in almost any proportion. But there is a great difference between the mixture of two substances and their chemical combination. Metals which melt nearly at the same temperature may be mixed from that very circumstance in any proportion; but substances can combine chemically only in one proportion. This observation, which is certainly of importance, was first made, as far as we know, by Mr Keir ‡. The alloy of silver and gold is of a greenish colour; but its properties have not yet been accurately examined.

‡ Translation of Macquer's *Dict. art. Alloy.*

78
Becomes tarnished by exposure.

Silver is not effected by water, nor by exposure to the air; but Mr Proust has remarked, that when long exposed in places frequented by men, as in churches, theatres, &c. it acquires a covering of a violet colour, which deprives it of its lustre and malleability. This covering, which forms a thin layer, can only be detached from the silver by bending it, or breaking it in pieces with a hammer. It was examined by Mr Proust, and found to be *sulphuret of silver*. He accounts for this transition of the silver into a *sulphuret*, by supposing

that a quantity of sulphur is constantly formed and exhaled by living bodies*.

The affinities of silver, according to Bergman, are as follows:

Lead,
Copper,
Mercury,
Bismuth,
Tin,
Gold,
Antimony,
Iron,
Manganese,
Zinc,
Arsenic,
Nickel,
Platinum,
Sulphurets of alkalies,
Sulphur,
Phosphorus.

SECT. III. Of Platinum.

THE metals hitherto described have been known to mankind from the earliest ages, and have been always in high estimation on account of their beauty, scarcity, ductility, and indestructibility. But platinum, though perhaps inferior to them in none of these qualities, and certainly far superior in others, was unknown, as a distinct metal, before the year 1752 (1).

It has been found only in America, in Choco in Peru, and in the mine of Santa Fe, near Carthagena. The workmen of these mines must no doubt have been early acquainted with it; but they seem to have paid very little attention to it. It was unknown in Europe till Mr Wood brought some of it from Jamaica in 1741. Soon after it was noticed by Don Antonio de Ulloa, a Spanish mathematician, who had accompanied the French academicians to Peru in their voyage to measure a degree of the meridian. In the year 1752 it was examined by Scheffer of Sweden, and discovered by him to be a new metal, approaching very much to the nature of gold, and therefore called by him *aurum album*,

80
Discovery of platinum.

(H) Metals combined together are called *alloys* or *allays*.

(1) Father Cortinovis, indeed, has attempted to prove that this metal was the *electrum* of the ancients. See the *Chemical Annals of Brugnatelli*, 1790. That the *electrum* of the ancients was a metal, and a very valuable one, is evident from many of the ancient writers, particularly Homer. The following lines of Claudian are alone sufficient to prove it:

*Atria cinsit ebur, trabibus solidatur abenis
Culmen et in celsas surgunt electra columnas.* L. I. v. 164.

Pliny gives us an account of it in his Natural History. He informs us that it was a composition of silver and gold; and that by candle-light it shone with more splendor than silver. The ancients made cups, statues, and columns of it. Now, had it been our platinum, is it not rather extraordinary that no traces of a metal, which must have been pretty abundant, should be perceptible in any part of the old continent?

As the passage of Pliny contains the fullest account of *electrum* to be found in any ancient author, we shall give it in his own words, that every one may have it in his power to judge whether or not the description will apply to the platinum of the moderns.

“Omni auro inest argentum vario pondere.—Ubicumque quinta argenti portio est, *electrum* vocatur: Scrobes eæ reperiantur in Canaliensi. Fit et cura *electrum* argento addito. Quod si quintam portionem excessit, incudibus non resistit. Et *electro* auctoritas, Homero teste, qui Menelai regiam auro, *electro*, argento, ebone fulgere tradit. Minervæ templum habet Lindos insulæ Rhodiorum in quo Helena sacravit calicem ex *electro*.—*Electri* natura est ad lucernarum lumina clarius argento splendere. Quod est nativum, et venena deprehendit. Namque discurrunt in calicibus arcus celestibus similes cum igneo stridore, et geminatione prædicunt.”—*Lib. xxxiii. cap. iv.*

Part I.

Platinum. *album, white gold.* Soon after it was examined by Lewis, Margraf, Macquer and Beaumé, Morveau, Bergman, and many other illustrious chemists.

81 Its properties. Platinum, when pure, is of a white colour like silver, but not so bright (κ). It has no taste nor smell.

It is both ductile and malleable; but the precise degree has not yet been ascertained. It has been drawn into a wire of $\frac{1}{10}$ of an inch in diameter. This wire admitted of being flattened, and had more strength than

Witbering a wire of silver or gold of the same size.

It is exceedingly difficult to fuse it. Macquer and Beaumé succeeded by means of a powerful burning-glass. It melts more easily when mixed with other substances. Its fixity is still greater than its infusibility. If the strongest fires cannot melt it, much less can they volatilize it.

† Kirwan's Miner. ii. 103. Its hardness is 7,5 †. Its specific gravity, after being hammered, is 23,000; so that it is by far the heaviest body known.

Some of the experiments which have been made on platinum seem to prove that it may be oxidated by the application of a violent heat. The oxide of this metal may be easily formed by dissolving platinum in nitromuriatic acid, and precipitating it by means of an earth or potash. The various oxides of platinum have never yet been examined with accuracy. The one at present best known possesses, as Mr Berthollet has proved, the properties of an acid.

The sulphuret of platinum is unknown.

82 Phosphuret of platinum. By mixing together an ounce of platinum, an ounce of phosphoric glass, and a dram of powdered charcoal, and applying a heat of about 32° Wedgewood, Mr Pelletier formed a phosphuret of platinum weighing more than an ounce. It was partly in the form of a button, and partly in cubic crystals. It was covered above by a blackish glass. It was of a silver white colour, very brittle, and hard enough to strike fire with steel. When exposed to a fire strong enough to melt it, the phosphorus was disengaged, and burnt on the surface †.

† Ann. de Chim. i. 71. He found also, that when phosphorus was projected on red hot platinum, the metal instantly fused and formed a phosphuret. As heat expels the phosphorus, Mr Pelletier has proposed this as an easy method of purifying platinum §.

§ Ibid. xiii. 105. Platinum does not seem capable of combining with carbon.

It is not in the least affected by the action of water or air.

83 Alloys of platinum. 1. When gold and platinum are exposed to a strong heat, they combine, and form an alloy of a much whiter colour, but nearly as ductile as gold. The proportions of the ingredients are not known. When $\frac{1}{4}$ only of the alloy is platinum, the gold is scarcely altered in colour.

2. Whether silver and platinum combine chemically has not yet been properly ascertained. When fused together (for which a very strong heat is necessary), they form a mixture, not so ductile as silver, but harder and less white. The two metals are separated by keep-

ing them for some time in the state of fusion; the platinum sinking to the bottom from its weight. This circumstance would induce one to suppose that there is very little affinity between them.

Mercury.

SECT. IV. Of Mercury.

MERCURY, called also *quicksilver*, was known to the ancients, and seems to have been employed by them in gilding.

It is of a white colour, exactly like that of polished silver. It has no taste, but acquires a slight odour when rubbed between the hands.

84 Properties of mercury.

Its specific gravity is 13,568*.

* Brisson.

It differs from all other metals in always existing, at the common temperature of the atmosphere, in a state of fluidity. It freezes at -39° †; or, which is the same † See Mac-nab's Experiments, Phil. Trans. thing, it ceases to be a solid, and melts whenever it is placed in a temperature above -39°. It boils at the temperature of 600°.

From the experiments made on frozen mercury in Russia, Hudson's Bay, and Britain, we know that this metal, when solid, is malleable; but the extreme difficulty of examining it in that state, on account of the lowness of the temperature, has rendered it hitherto impossible to ascertain the precise degree either of its malleability, ductility, or hardness.

Mercury is capable of combining with oxygen, and of forming oxides, differing from each other in the quantity of oxygen which they contain. The oxides of mercury, at present known, are the *black*, the *yellow*, and the *red*.

85 It forms oxides;

1. When mercury is agitated for some time in contact with oxygen gas, or atmospheric air, it is partly converted into a greyish black powder, and at the same time part of the oxygen disappears. This is the *black oxide of mercury*. It is not known how much oxygen it contains, nor even whether the whole of the mercury which composes it be actually combined with oxygen.

86 The black oxide,

2. The best way of forming the yellow oxide is to dissolve mercury, either in boiling sulphuric acid or in cold nitric acid. During its solution, it deprives these acids of just as much oxygen as is necessary to convert it into a yellow oxide; and if potash or lime be afterwards added to the solution, it precipitates, and may be obtained pure by washing it with water. It is a bright yellow-coloured powder, which acts very powerfully as an emetic. From the observations of Bergman, it appears that it is composed of about 96,8 parts of mercury, and 3,2 of oxygen †.

87 Yellow oxide,

3. The *red oxide* of mercury may be prepared, either by distilling nitric acid off the metal repeatedly, or by keeping mercury for a long time exposed to a heat sufficient to evaporate it while it is in contact with air. When formed by the first process, it was formerly called *red precipitate*; when by the last, *precipitate per se*. It is a beautiful red powder, or rather small red crystals, which have some escharotic qualities. When prepared by the second process, the heat must not be much below 600° nor much above 800°, otherwise no union would take place;

† Kirwan's Miner. ii. 489.

88 And red oxide.

(κ) To this colour it owes its name. *Plata*, in Spanish, is *silver*; and *platina*, *little silver*, was the name first given to the metal. Bergman changed that name into *platinum*, that the Latin names of all the metals might have the same termination and gender. It was, however, first called *platinum* by Linnæus.

Mercury. place; and it must be continued for some weeks. From the experiments of Mr Kirwan, it appears to contain 92,6 parts of mercury and 7,4 of oxygen*.

* Kirwan's Miner. ii. 489. These oxides may be decomposed by the application of a heat amounting to 1200°. The oxygen flies off in the form of gas, and running mercury remains behind.

89 Their affinities. The affinities of the oxides of mercury, according to Bergman, are as follows:

Sebacic acid,
Muriatic,
Oxalic,
Succinic,
Arsenic,
Phosphoric,
Sulphuric,
Benzoic (L)?
Saccholaric,
Tartarous,
Citric,
Sulphurous,
Nitric,
Fluoric,
Zoonic (M)?
Acetous,
Boracic,
Prussic,
Carbonic.

97 Black sulphuret of mercury. When two parts of mercury and three parts of flowers of sulphur are triturated for some time together, or when equal parts of mercury and melted sulphur are mixed together—they combine, and form a black powder, formerly called *ethiops mineral*, and now *black sulphuret of mercury*.

91 Red sulphuret. When 300 grains of mercury and 68 of sulphur, with a few drops of solution of potash to moisten them, are triturated for some time in a porcelain cup by means of a glass pestle, black oxide of mercury is produced. Add to this 160 grains of potash, dissolved in as much water. Heat the vessel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, so that the oxide may be constantly covered to the depth of near an inch. The trituration must be continued about two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which usually happens when a large part of the fluid is evaporated. It then passes very rapidly to a red. No more water is to be added; but the trituration is to be continued without interruption. When the mass has acquired the consistence of a jelly, the red colour becomes more and more bright, with an incredible degree of quickness. The instant the colour has acquired its utmost beauty, the heat must be withdrawn, otherwise the red passes to a dirty brown. This red powder is the red sulphuret of mercury, called formerly *cinnabar*, and, when reduced to a fine powder, *vermilion* (N). The process

above described has been lately discovered by Mr Kirchoff, and is by far the simplest and cheapest mode of forming red sulphuret with which we are acquainted*. * Nicholson's Journ. ii. 1. Count De Mouslin Pouschin has discovered, that its passing to a brown colour may be prevented by taking it from the fire as soon as it has acquired a red colour, and placing it for two or three days in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. During this exposure, the red colour gradually improves, and at last becomes excellent. He discovered also, that when this sulphuret is exposed to a strong heat, it becomes instantly brown, and then passes into a dark violet; when taken from the fire it passes instantly to a beautiful carmine red†. † Ibid. p. 7.

The difference between these two sulphurets has never yet been ascertained. One would be apt to suspect at first that the black sulphuret consists of the real sulphuret of mercury combined with sulphur; the red, of the sulphuret of mercury combined with mercury, and that the real sulphuret of mercury was not yet accurately known. But it cannot be doubted that, during the formation of the *red sulphuret*, according to Kirchoff's process, there is an absorption of oxygen. The phenomena above described point out *that* almost incontestibly; and we observed, on attempting to repeat the experiment, that the black sulphuret, during its trituration, emitted sulphurated hydrogen gas. Perhaps, then, the mercury may be oxidated. We suspected at first that part of the sulphur might be converted into an acid; but on attempting an alteration of the process, in consequence of that supposition, we could not succeed.

The red sulphuret of mercury is found naturally in several parts of the world. It used to be prepared by forming a black sulphuret with three parts of sulphur and one of mercury, and then setting fire to it. Part of the sulphur is burnt, and there remains behind a violet-coloured body, which is powdered and put into a glass vessel, to the bottom of which a red heat is applied. A reddish brown substance sublimes, which is red *sulphuret of mercury*; but its colour is not nearly equal to that which is prepared by Kirchoff's process.

92 Mr Pelletier, after several unsuccessful attempts to Phosphuret form phosphuret of mercury, at last succeeded by dis- of mercury. tilling a mixture of red oxide of mercury and phosphorus. Part of the phosphorus combined with the oxygen of the oxide, and was converted into an acid; the rest combined with the mercury.

Phosphuret of mercury is of a black colour, of a pretty solid consistence, and capable of being cut with a knife. When exposed to the air, it exhales vapours of phosphorus ‡.

Mercury does not seem capable of combining with carbon.

The combinations of mercury with the other metals are called *amalgams*. 93 its amal- gam.

1. The amalgam of gold forms very readily, because there is a very strong affinity between the two metals. If a bit of gold be dipped into mercury, its surface, by combining with mercury, becomes as white as silver.

The

(L) Benzoat of mercury is decomposed by sulphuric acid. Tromsdorf, *Ann. de Chim.* xi. 316.

(M) Zoonic acid decomposes the acetite of mercury. Berthollet.

(N) The word *vermilion* is derived from the French word *vermeil*, which comes from *vermiculus* or *vermiculum*; names given in the middle ages to the *kermes* or *coccus ilicis*, well known as a red dye. *Vermilion* originally signified the red dye of the kermes. See *Beckmann's Hist. of Inventions*, ii. 180.

Mercury. The easiest way of forming this amalgam is to throw small pieces of red hot gold into mercury. The proportions of the ingredients are not easily determined, because the amalgam has an affinity both for the gold and the mercury; in consequence of which they appear to combine in any proportion. Most probably it is composed of two parts of gold and one of mercury. The combination is formed most readily in these proportions; and if too much mercury be added, it may be separated by filtration. The amalgam is of a white colour, and of the consistence of butter*. This amalgam crystallizes in quadrangular prisms; which crystals, according to the Dijon academicians, are composed of six parts of mercury and one of gold. It is much used in gilding.

* Keir's Notes on Macquer's Diæt art, Amalgam.

2. The amalgam of silver is made in the same manner. It forms dendritical crystals, which, according to the Dijon academicians, contain eight parts of mercury and one of silver. Gellert was the first who remarked that its specific gravity was greater than that of mercury, though that of silver be less.

3. Dr Lewis attempted to form an amalgam of platinum, but hardly succeeded after a labour which lasted for several weeks. Mr Morveau succeeded by means of heat †. But a much more expeditious method has been lately discovered by Count Mouffin Poufchin. He took a dram of the orange-coloured salt, composed of oxide of platinum and ammonia (o), and triturated it with an equal weight of mercury in a mortar of chalcedony. In a few minutes the salt became brown, and afterwards acquired a greenish shade. The matter was reduced to a very fine powder. Another dram of mercury was added, and the trituration continued: The matter became grey. A third dram of mercury began to form an amalgam; and six drams made the amalgam perfect. The whole operation scarce lasted 20 minutes. Mercury was added till it amounted to nine times the weight of the salt, and yet the amalgam continued very tenacious. It was easily spread out under the pestle; it received the impression of the most delicate seals, and had a very close and brilliant grain. This amalgam is decomposed, and the mercury passes to the state of black oxide by the simple contact of several of the metals and a great number of animal matters. This effect even takes place on rubbing it between the fingers ‡.

† Ann. de Chim. xxiv. 205.

‡ Ibid. 94. Affinities.

The affinities of mercury, as ascertained by the experiments of Morveau (P), are as follows:

- Gold,
- Silver,
- Tin,
- Lead,
- Bismuth,
- Zinc,
- Copper,
- Antimony,
- Arsenic (Q),
- Iron.

SECT. V. Of Copper.

EXCEPT gold and silver, copper seems to have been

more early known than any other metal. In the first ages of the world, before the method of working iron was discovered, copper was a principal ingredient in all domestic utensils and instruments of war. Even during the Trojan war, as we learn from Homer, the combatants had no other armour but what was made of bronze, which is a mixture of copper and tin. The word copper is derived from the island of Cyprus, where it was first discovered, or at least wrought to any extent, by the Greeks.

Copper is of a pale red colour with a shade of yellow. Its taste is styptic and nauseous; and when rubbed it emits a disagreeable smell. It possesses a considerable degree of malleability, though less than silver. Its tenacity is such, that a wire of $\frac{1}{16}$ of an inch in diameter can sustain a weight of 299 $\frac{1}{4}$ pounds without breaking*.

95 Properties of copper.

Its hardness is 8 †. Its specific gravity, when not hammered, is 7,788; when wire-drawn, 8,878 ‡. The specific gravity of Japan copper is 9,000 §; that of Swedish copper, 9,3243 ||.

* Macquer's Diæt
† Kirwan's Miner. ii. 127.
‡ Brisson.
§ Keir's Notes on Macquer's Diæt.
|| Bergman, ii. 263.

It melts at 27° Wedgewood; according to the calculation of the Dijon academicians, at 1449° Fahrenheit. When allowed to cool slowly, it assumes a crystalline form. The Abbe Mongé, to whom we owe many valuable experiments on the crystallization of metals, informs us, that these crystals are quadrangular pyramids, frequently inserted into one another.

When copper is heated red hot in contact with air, it is soon covered with a brown earthy crust, which may be easily separated by hammering or by plunging the metal into water. If the heat be continued, another scale of the same kind soon forms; and by continuing the process the whole metal may be converted into an earthy-like crust, which is merely a combination of copper and oxygen, and is therefore called brown oxide of copper. It is composed of about 84 parts of copper and 16 of oxygen*.

96 Brown oxide of copper.

When copper is dissolved in sulphuric acid, and precipitated by means of lime, it falls in the form of a blue-coloured powder, which is the blue oxide of copper. If this oxide of copper be dried in the open air, it assumes a green colour, and is then called the green oxide of copper. This last oxide may also be produced by distilling a sufficient quantity of nitric acid off copper. Little satisfactory is yet known with respect to these oxides; it has not even been ascertained whether the blue and green be really two different oxides, or whether the difference in colour be owing to some other cause. It is probable, however, that the green oxide contains more oxygen than the blue; because the blue oxide assumes a green colour when exposed for some time to the open air, during which it may be supposed to absorb oxygen. An experiment of Fourcroy proves incontestibly, that the brown oxide contains less oxygen than the green. He converted the green oxide into the brown by applying heat; and during the distillation obtained oxygen gas †.

* Kirwan's Miner. ii. 437.
97 Blue and green oxides.

The affinities of the oxides of copper, according to Bergman, are as follows:

- Pyro-mucous acid ‡
- Oxalic,

† Fourcroy iii. 101.
98 Their affinities.
‡ Strickel.

Tartarous,

(o) Ammonia is an alkali hereafter to be described. It is often called, in English, hartshorn.
(p) We shall have occasion to consider these celebrated experiments afterwards.
(q) These two are added from Bergman. Bergman places lead before tin, and zinc before bismuth.

Copper.

- Tartarous,
- Muriatic,
- Sulphuric,
- Saccholarctic,
- Nitric,
- Sebacic,
- Arsenic,
- Phosphoric,
- Succinic,
- Fluoric,
- Citric,
- Formic,
- Lactic,
- Acetous,
- Boracic,
- Prussic,
- Carbonic,
- Fixed alkalies,
- Ammonia,
- Fixed oils.

Iron.

3. Platinum combines readily with copper. The alloy is much more fusible than platinum; it is ductile, hard, takes a fine polish, and is not liable to tarnish. This alloy has been employed with advantage for composing the mirrors of reflecting telescopes.

4. The amalgam of copper cannot be formed by simply mixing that metal with mercury, nor even by the application of heat; because the heat necessary to melt copper sublimes mercury. Dr Lewis has given us several processes for forming this amalgam. One of the simplest is to triturate mercury with a quantity of common salt and verdigrise; a substance composed of oxide of copper and vinegar. The theory of this process is not very obvious.

The affinities of copper are, according to Bergman, as follows:

- Gold,
- Silver,
- Arsenic,
- Iron,
- Manganese,
- Zinc,
- Antimony,
- Platinum,
- Tin,
- Lead,
- Nickel,
- Bismuth,
- Cobalt,
- Mercury,
- Sulphuret of alkali,
- Sulphur,
- Phosphorus.

102

When copper is long exposed to the air, its surface becomes covered over with a green crust, which is *green oxide of copper*. This oxidation never penetrates beyond the surface.

Copper is not attacked by water at the boiling temperature; but if cold water be allowed to remain long on its surface, the metal becomes partly oxidated.

⁹⁹ Sulphuret of copper. Sulphur mixes readily with copper. The combination may be formed by mixing the ingredients together and applying a pretty strong heat. *Sulphuret of copper* is brittle, softer than copper, of a black colour externally, and within of a leaden grey. It is composed, according to Kirwan's experiments, of 81 parts of copper

* Kirwan's and 19 of sulphur*.

¹⁰⁰ Phosphuret of copper. Mr Pelletier formed *phosphuret of copper* by melting together one ounce of copper, one ounce of phosphoric glass, and one dram of charcoal. It was of a white colour. On exposure to the air, it lost its lustre and became blackish †. Margraf was the first person that formed this phosphuret. His method was to distil phosphorus and brown oxide of copper together. It is formed most easily by projecting phosphorus into red hot copper. According to Pelletier, it contains 20 parts of phosphorus and 80 of copper ‡. This phosphuret is harder than iron: It is not ductile, and yet cannot easily be pulverised. Its specific gravity is 7,1220. It crystallizes in tetrahedral prisms §.

† Ibid. xiii. 3.

§ Sage Journ. de Phys. xxxviii. 468. 101 Alloys of copper

1. Copper combines readily with gold when the two metals are melted together. The compound is of a reddish colour, more fusible than gold, but less ductile. The proportions of the ingredients which form this alloy are not known; nor would it be easy to ascertain them, as the two metals are almost equally fusible. The current gold of this country is composed of 11 parts of gold and one part of copper.

2. The alloy of copper and silver is made as easily as that of gold, and the properties are equally unknown. It is harder and more sonorous than silver. The current silver coin of Britain is composed of 15 parts of silver and one of copper.

SECT. VI. Of Iron.

¹⁰³ IRON, the most abundant and most useful of all the metals, was neither known so early, nor wrought so easily, as gold, silver, and copper. For its discovery we must have recourse to the nations of the east, among whom, indeed, almost all the arts and sciences first sprung up. The writings of Moses (who was born about 1635 years before Christ) furnish us with the amplest proof at how early a period it was known in Egypt and Phœnicia. He mentions furnaces for working iron*, ores from which it was extracted †; and tells us that swords ‡, knives §, axes ||, and tools for cutting stones ¶, were then made of that metal. How many ages before the birth of Moses iron must have been discovered in these countries, we may perhaps conceive, if we reflect, that the knowledge of iron was brought over from Phrygia to Greece by the Dactyli*, who settled in Crete during the reign of Minos I. about 1431 years before Christ; yet during the Trojan war, which happened 200 years after that period, iron was in such high estimation, that Achilles proposed a ball of it as one of his prizes during the games which he celebrated in honour of Patroclus (R). At that period none of their weapons were formed of iron. Now if the Greeks in 200 years had made so little progress in an art which they learned from others, how long must it

* Deut. iv. 20.

† Ibid. viii.

‡ Numb. xxxv. 16.

§ Levit. i. 17.

|| Deut. xviii. 5.

¶ Ibid. xxvii. 5.

* Hesiod, as quoted by Pliny, lib. vii. c. 57.

(R) Δαταρ Πηλεΐδης δεικεν σολον κυτοχοωνον, 'Ον πριν μεν ριπασσε μεγα σθενος Ηετιωνος' Αλλ' ητοι τον επερεν ποδαρχης διος Αχιλλειου,

Iron.

Fluoric,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic.

Part I.

Iron. it have taken the Egyptians, Phrygians, Chalybes, or whatever nation first discovered the art of working iron, to have made that progress in it which we find they had done in the days of Moses?

104
It's properties. Iron, when fresh broken, is of a bluish grey colour. It has a styptic taste, and emits a smell when rubbed.

It is malleable and ductile in every temperature; and its malleability is increased in proportion as the temperature augments. Its tenacity is such, that an iron wire $\frac{1}{10}$ of an inch in diameter sustains a weight of 450

* Macquer's Dict. pounds without breaking *.

Its hardness is such, that it may be easily reduced to powder by the application of a file. Its specific gravity is 7,788. It is infusible in the strongest heats hitherto produced.

It is attracted by the magnet or loadstone, and is itself capable of becoming magnetic; but it retains this property only for a very short time.

It is not hardened by being plunged into liquids while hot, nor softened by being cooled slowly.

Iron combines with oxygen very readily. When kindled in oxygen gas, it burns with great rapidity and splendor, and is in this manner converted into an oxide. It is converted into an oxide also when surrounded by moist air, or when plunged in water; because it has a stronger affinity for oxygen than hydrogen has, and is therefore capable of decomposing water.

105
Forms two oxides. Mr Proust has lately proved, that there are only two oxides of iron, the green and the brown or red, and that all the other supposed oxides are merely mixtures of these two in various proportions †.

† Ann. de Chim. xxiii. 85. and Nicholson's Journal, i. 453. † Mem. Acad. Par. 1782. The green oxide may be obtained by dissolving iron in sulphuric acid, and then precipitating it by potash. It is a light, green-coloured, earthy-like substance, composed, as Mr Lavoisier has shewn, of 27 parts of oxygen, and 73 of iron †. When this oxide is exposed to the air, it quickly absorbs more oxygen, and is converted into a brown powder, which is the brown oxide. Mr Proust has proved that it contains 52 parts of iron and 48 of oxygen. This oxide is well known under the name of rust of iron, which is generally, however, or perhaps always, combined with carbonic acid gas.

106
The affinities. The affinities of these oxides, according to Bergman, are as follows:

- Gallic acid?
- Oxalic acid,
- Tartarous,
- Camphoric §,
- Sulphuric,
- Saccholaetic,
- Muriatic,
- Pyromucous ||,
- Nitric,
- Sebacic,
- Phosphoric,
- Arfenic,

§ LaGrange.

|| Sebricquel.

SUPPL. VOL. I. Part. I.

107
Sulphuret. Iron unites readily with sulphur. Sulphuret of iron, formerly called pyrites, is found ready formed in many parts of the world. It is not easy to determine the proportions of its ingredients, because it is capable of combining both with iron and sulphur, and consequently, if there happens to be any excess of either during its formation, it takes it up. Perhaps the proportions are not far from equal parts of sulphur and of iron. It is of a pale yellow or brownish colour, and is capable of assuming a crystalline form. Its specific gravity is about 4,000. When placed upon the fire it precipitates; and at a red heat loses its yellow colour, and becomes of an iron grey, excepting its surface, which is of a bright red. It melts at 102° Wedgwood in a covered crucible into a bluish slag, somewhat porous internally*. When exposed to air and moisture, the sulphur, as happens in all sulphurets, gradually absorbs oxygen, and is converted into an acid. * Kirwan's Miner. ii. 76.

If iron filings and sulphur be mixed together, and formed into a paste with water, the sulphur decomposes the water, and absorbs oxygen so rapidly, that the mixture takes fire, even though it be buried under ground. This phenomenon was first discovered by Homberg; and it is considered as affording an explanation of the origin of volcanoes. The native sulphuret of iron has been observed more than once to take fire on being suddenly moistened with water.

108
Phosphu-rect. Iron combines readily with phosphorus, and forms phosphuret of iron; to which Bergman, who first discovered it, gave the name of siderum.

There is a particular kind of iron, known by the name of cold short iron, because it is brittle when cold, though it be malleable when hot. Bergman was employed at Upsal in examining the cause of this property, while Meyer was occupied at Stetin with the same investigation; and both of them discovered, nearly at the same time, that, by means of sulphuric acid, a white powder could be separated from this kind of iron, which by the usual process they converted into a metal of a dark steel grey, exceedingly brittle, and not very soluble in acids. Its specific gravity was 6,700; it was not so fusible as copper; and when combined with iron rendered it cold short. Both of them concluded that this substance was a new metal; and Bergman gave it the name of siderum. But Klaproth soon after recollecting that the salt composed of phosphoric acid and iron bore a great resemblance to the white powder obtained from cold short iron, suspected the presence of phosphoric

G g

Τον δ' ἀγέρ' ἐν νηυσὶ αὐτῶν ἀλλοίσι κταίεσσι.
Στῆ δ' ὄρθος, καὶ μύθων ἐν Ἀργείοισιν εἴπεν·
Ὀρνυσθ', οἳ καὶ τῆτι ἀέθλυ πειρσασθ'·
Εἰ οἳ καὶ μάλλα πολλὸν ἀποκρῶσι πῖνες ἀγροί,
'Ἐξεί μιν καὶ περιπλομένους ἐνιαυτὸς
Χρῶμενος· ἢ μὲν γὰρ οἳ ἀτεμβόμενος γι σιδηρῷ
Ποίμνῃ, ἠδ' ἀριστηρ, εἰς' ἐς πόλιν, ἀλλὰ παρῆξεν.

Iliad, xxiii. l. 826.

phosphoric acid in this new metal. To decide the point, he combined phosphoric acid and iron, and obtained, by heating it in a crucible along with charcoal powder (s), a substance exactly resembling the new metal. Meyer, when Klaproth communicated to him this discovery, informed him that he had already satisfied himself, by a more accurate examination, that siderum contained phosphoric acid. Soon after this Scheele actually decomposed the white powder obtained from cold short iron, and thereby demonstrated, that it was composed of phosphoric acid and iron. The siderum of Bergman, however, is composed of phosphorus and iron, the phosphoric acid being deprived of its oxygen during the *reduction*; or it is phosphuret of iron. It may be formed by fusing in a crucible an ounce of phosphoric glass, an ounce of iron, and half a dram of charcoal powder. It is very brittle, and appears white when broken. When exposed to a strong heat, it melts, and the phosphorus is dissipated*. It may be formed also by melting together equal parts of phosphoric glass and iron filings. Part of the iron combines with the oxygen of the phosphoric glass, and is vitrified; the rest forms the phosphuret, which sinks to the bottom of the crucible. It may be formed also by dropping small bits of phosphorus into iron filings heated red hot †. The proportions of the ingredients of this phosphuret have not yet been determined.

• Pelletier, Ann. de Chim. i. 104.

† Id. Ann. de Chim. xiii. 113. 109. And carburet of iron.

Iron likewise combines with carbon, and forms a *carburet*. Carburet of iron has been long known and used in the arts under the names of *plumbago* and *black lead*. It is of a dark iron grey or blue colour, and has something of a metallic lustre. It has a greasy feel, and blackens the fingers, or any other substance to which it is applied. It is found in many parts of the world, especially in England, where it is manufactured into pencils. It is not affected by the most violent heat as long as air is excluded, nor is it in the least altered by simple exposure to the air, or to water. Its nature was first investigated by Scheele; who proved, by a very ingenious analysis, that it could be converted almost wholly into carbonic acid gas, and that the small residuum was iron. It follows from this analysis, that it is composed of carbon and iron; for the carbon, during its combustion, had been converted into carbonic acid gas. By the subsequent experiments of Pelletier and other French chemists, it has been shewn to consist nearly of nine parts of carbon to one of iron.

110 Varieties of iron.

111 Wrought iron.

There are a great many varieties of iron, which artists distinguish by particular names; but all of them may be reduced under one or other of the three following states: *Wrought iron* (or simply *iron*), *steel*, and *cast or raw iron*.

WROUGHT IRON is the substance which we have been hitherto describing. As it has never yet been decomposed, we consider it when pure as a simple body; but it has seldom or never been found without some small mixture of foreign substances. These substances are either some of the other metals, or oxygen, carbon, or phosphorus.

112 Steel.

STEEL is distinguished from iron by the following properties.

It is so hard as to be unmalleable while cold, or at

least it acquires this property by being immersed while ignited into a cold liquid: for this immersion, though it has no effect upon *iron*, adds greatly to the hardness of *steel*.

It is brittle, resists the file, cuts glass, affords sparks with flint, and retains the magnetic virtue for any length of time.

It loses this hardness by being ignited and cooled very slowly.

It melts at above 130° Wedgewood. It is malleable when red hot, but scarcely so when raised to a white heat.

It may be hammered out into much thinner plates than iron. It is more sonorous; and its specific gravity, when hammered, is greater than that of iron.

By being repeatedly ignited in an open vessel, and hammered, it becomes *wrought iron**.

CAST IRON is distinguished by the following properties:

It is scarcely malleable at any temperature. It is generally so hard as to resist the file. It can neither be hardened nor softened as steel can by ignition and cooling. It is exceedingly brittle. It melts at 130° Wedgewood. It is more sonorous than steel †.

Cast iron is converted into wrought iron by exposing it for a considerable time in a furnace to a heat sufficiently strong to melt it. During the process it is constantly stirred by a workman, that every part of it may be equally exposed to the air. In about an hour the hottest part of the mass begins to heave and swell, and to emit a lambent blue flame. This continues nearly an hour; and by that time the conversion is completed. The heaving is evidently produced by the emission of an elastic fluid ‡.

Wrought iron may be converted into steel by being kept for some hours in a strong red heat, surrounded with charcoal powder in a covered crucible. By this process, which is called *cementation*, the iron gains some weight.

These different kinds of iron have been long known, and the converting of them into each other has been practised in very remote ages. Many attempts have been made to explain the manner in which this conversion is accomplished. According to Pliny, steel owes its peculiar properties chiefly to the water into which it is plunged in order to be cooled §. Beccher supposed that fire was the only agent; that it entered into the iron, and converted it into steel. Reaumur was the first who attended accurately to the process; and his numerous experiments have certainly contributed to elucidate the subject. He supposed that iron was converted into steel by combining with saline and oily or sulphureous particles, and that these were introduced by the fire. But it was the analysis of Bergman, published in 1781, that first paved the way to the explanation of the nature of these different species of iron.

By dissolving in diluted sulphuric acid 100 parts of cast iron, he obtained 40 ounce measures of hydrogen; from 100 parts of steel he obtained 48 ounce measures; and from 100 parts of wrought iron, 50 ounce measures. Now as the hydrogen is produced by the property which iron has of decomposing water and uniting with its oxygen, it is evident that the greater the quantity of hydrogen obtained,

* Dr Pearson on Wootz, Phil. Transf. 113

† Ibid.

‡ Beddoes, Phil. Transf. 1791.

§ Pliny, l. xxxiv. 14.

Iron.

Iron.

tained, with the more oxygen does the iron combine. But the quantities of iron were equal; they ought therefore to have combined with equal quantities of oxygen. But it is evident, from the quantities of hydrogen obtained, that the cast iron received less oxygen than either of the other two: cast iron therefore must contain already some oxygen, since it requires less than the other two species in order to be saturated. Here then is one difference between cast iron and the other two kinds; it contains oxygen. Steel, on the contrary, does not appear to contain any oxygen. The difference between the quantity of hydrogen produced during its solution and that of wrought iron, which contains no oxygen, is exceedingly small, and it has been found to diminish in proportion to the purity of the steel.

From 100 parts of cast iron Bergman obtained 2,2 of plumbago, or $\frac{1}{27}$; from 100 parts of steel, 0,5, or $\frac{1}{200}$; and from 100 parts of wrought iron, 0,12, or $\frac{1}{83}$. Now plumbago is composed of $\frac{1}{20}$ ths of carbon; cast iron therefore contains a considerable quantity of carbon, steel a smaller quantity, and wrought iron a very minute portion, which diminishes according to its purity, and would vanish altogether if iron could be obtained perfectly pure. Mr Grignon, in his notes on this analysis, endeavoured to prove that plumbago was not essentially a part of cast iron and steel, but that it was merely accidentally present. But Bergman, after considering his objections, wrote to Morveau on the 18th November 1783. "I will acknowledge my mistake whenever Mr Grignon sends me a single bit of cast iron or steel which does not contain plumbago; and I beg of you, my dear friend, to endeavour to discover some such, and to send them to me; for if I am wrong, I wish to be undeceived as soon as possible*." This was almost the last action of the illustrious Bergman. He died a few months after at the age of 49, leaving behind him a most brilliant reputation, which no man ever more deservedly acquired. His industry, his indefatigable, his astonishing industry, would alone have contributed much to establish his name; his extensive knowledge would alone have attracted the attention of philosophers; his ingenuity, penetration, and accurate judgment, would alone have secured the applause; and his candour and love of truth procured him the confidence and the esteem of the world.—But all these qualities were united in Bergman, and conspired to form one of the greatest men and noblest characters that ever adorned human nature.

The experiments of Bergman were fully confirmed by those of Morveau, Vandermonde, Monge, and Berthollet, who have likewise thrown a great deal of additional light on the subject. From all these experiments the following deductions may be made.

Wrought iron is a simple substance, and if perfectly pure would contain nothing but iron.

Steel is iron combined with carbon. The proportion of this last ingredient has not yet been ascertained; Dr Pearson fixes it at $\frac{1}{200}$ th part at a medium. Steel, in consequence of its composition, has been called by some chemists *carburet of iron*; but before assigning it that name, which has been also given to plumbago, it ought to be determined what are the proportions of carbon and iron which saturate each other. Is it the propor-

tion in which these two substances exist in steel, or that which forms plumbago? In the first case, plumbago is carburet of iron combined with carbon; in the second, steel is carburet combined with iron. Or is it some intermediate proportion? Till these points be determined, perhaps it would be better to continue the old names than to risk the imposing of false ones.

Cast iron is iron contaminated with various foreign substances, the proportions of which vary according to circumstances. These substances are chiefly oxide of iron and carbon, and sometimes silica (τ).

Bergman found a quantity of manganese in the iron and steel which he examined; but it appears from the experiments of Vauquelin, that his method of determining the presence of that metal was not accurate.

Mr Vauquelin* has lately analysed four kinds of steel with great care, and contrived his processes with much ingenuity. The result of his analysis is as follows:

First steel, composed of	}	Carbon, -	0,00789
		Silica, -	0,00315
		Phosphorus, -	0,00345
		Iron, -	0,98551
			I

Second steel, composed of	}	Carbon, -	0,00683
		Silica, -	0,00273
		Phosphorus, -	0,00827
		Iron, -	0,98217
			I

Third steel, composed of	}	Carbon, -	0,00789
		Silica, -	0,00315
		Phosphorus, -	0,00791
		Iron, -	0,98105
			I

Fourth steel, composed of	}	Carbon, -	0,00631
		Silica, -	0,00252
		Phosphorus, -	0,01520
		Iron, -	0,97597
			I

It cannot be concluded from these experiments that all steel contains phosphorus and silica; far less that these substances enter necessarily into the composition of steel. This may be the case, and former analyses may not have been nice enough to detect it; but before it can be admitted, it must be shewn that these substances are always present in steel, and that it loses its essential properties when deprived of them.

Iron combines with most metals.

1. The alloy of gold and iron is very hard, and might, according to Dr Lewis, who examined it, be employed with advantage in forming cutting instruments.

2. That iron combines with silver is certain, but hardly any thing is known about the nature of the compound.

3. Platinum is usually found alloyed with iron. Dr Lewis did not succeed in his attempts to unite these

G g 2

metals

(τ) An earth which shall be described in the next chapter.

* Morveau, Encycl. Méthod. Chimie, i. 448.

* Jour. de chimie. See Nicholson's Journal, i. 200
115 Vauquelin's analysis of steel.

Tin. metals by fusion, but he melted together cast iron and platinum. The alloy was excessively hard, and possessed ductility.

4. There is very little affinity between iron and mercury; they cannot therefore be amalgamated by simple mixture, even with the assistance of heat. Vogel affirms that he has produced an amalgam of iron by the following process: Pound one part of iron filings and two parts of alum in a mortar to a fine powder; then pour in two or three parts of mercury, and triturate till the substances be thoroughly mixed. Pour on a little water, and continue the trituration for about an hour. If then no particles of iron can be distinguished, pour on a little more water to wash out the alum, and then dry the amalgam. If particles of iron be perceptible, the trituration must be continued till they disappear*.

* *Ann. de Chim.* vi. 39.

5. Iron may be united to copper by fusion, but not without considerable difficulty. The alloy has been applied to no use.

117
Its affinities. The affinities of iron, according to Bergman, are as follows:

Nickel,
Cobalt,
Manganese,
Arsenic,
Copper,
Gold,
Silver,
Tin,
Antimony,
Platinum,
Bismuth,
Lead,
Mercury,
Sulphuret of alkali,
Carbon?
Phosphorus?
Sulphur?

SECT. VII. Of Tin.

THE Phenicians were the first of those nations which make a figure in ancient history that were acquainted with tin. They procured it from Spain† and from Britain, with which nations they carried on a very lucrative commerce. At how early a period they imported this metal we may easily conceive, if we recollect that it was in common use in the time of Moses‡.

† *Pliny*, l. 4. c. 34. and l. 34. c. 47.

‡ *Numbers*, xxxi. 22. 118
Properties of tin:

Tin is of a greyish white colour: it has a strong disagreeable taste, and emits a peculiar smell when rubbed.

It is very malleable; tin-leaf, or *tin-foil* as it is called, is about $\frac{1}{8000}$ th part of an inch thick, and it might be beat out into leaves as thin again if such were wanted for the purposes of art. Its ductility, however, is exceedingly imperfect; for a tin wire $\frac{1}{10}$ th of an inch in diameter, is capable of supporting only 49 pounds without breaking §. It is very flexible, and produces a crackling noise when bended.

§ *Maquer's Dictionary*.
|| *Kirwan's Miner.* ii. 195.

Its hardness is 6 ||. Its specific gravity is 7,291; after hammering, 7,299 ¶.

¶ *Brisson*.
* *Pajot, Jour. de Phys.* xxxviii. 50.

It melts at the temperature 410°, according to Dr Lewis; according to the Dijon academicians, at 419°. When heated red hot in close vessels it sublimes. It crystallizes in the form of a rhomboidal prism*.

Tin unites very readily with oxygen. When heated in contact with air, its surface soon becomes covered with a grey pellicle; when this is taken off, another appears soon after; and in this manner the whole metal may be converted into a dirty grey powder, which is the *grey oxide of tin*. It is composed, according to Fourcroy, of 90 parts of tin and 10 of oxygen.

Tin.
119
Oxides,

When tin is heated red hot in contact with air, it takes fire*, and burns with a very lively white flame, and is gradually sublimed. If the sublimate be examined, it is found to consist of a white powder; it is the *white oxide of tin*. The white oxide is perhaps never obtained quite pure by this process; it seems always to contain a mixture of *grey oxide*: but it may be obtained pure by pouring nitric acid upon tin, and then drying it. That metal having a much stronger attraction for oxygen than azot has, decomposes the acid with the greatest rapidity, and assumes the appearance of a white powder, which is the *white oxide*. This oxide possesses many of the properties of an acid, and is therefore often called *stannic acid*. It seems to consist of about 77 parts of tin and 23 of oxygen †.

* *Coeffroy*.

† *Kirwan's Miner.* ii. 488.

The affinities of the grey oxide of tin, according to Bergman, are as follows:

Pyromucous acid ‡,
Sebacic acid,
Tartaric,
Muriatic,
Sulphuric,
Oxalic,
Arsenic,
Phosphoric,
Nitric,
Succinic,
Fluoric,
Saccholactic,
Citric,
Formic,
Lactic,
Acetous,
Boracic,
Prussic.

‡ *Schrickel*.

Tin combines readily with sulphur. This sulphuret¹²⁰ may be formed by fusing the two ingredients together. It is brittle, heavier than tin, and not so fusible. It is of a bluish colour and lamellated structure, and is capable of crystallizing. According to Bergman, it is composed of 80 parts of tin and 20 of sulphur; according to Pelletier, of 85 parts of tin and 15 of sulphur §. § *Ann. de Chim.* xiii. 237.

Sulphur likewise combines with the white oxide of tin, by mixing them together, and applying a gentle heat ||. This compound has been called *aurum musivum*. || *Pelletier*, It is a mass consisting of beautiful gold-coloured flakes, *ibid.* p. 297. and is used as a paint. It is composed of about 40 parts of sulphur and 60 of white oxide of tin ¶. The process ¶ *Ibid.* 293. for making this substance was formerly very complicated. Pelletier first demonstrated its real composition, and was hence enabled to make many important improvements in the manner of manufacturing it*.

* See his *Memoire, Ann. de Chim.* xiii. 280.

Phosphorus is easily combined with tin, by melting in a crucible equal parts of filings of tin and phosphoric glass. Tin has a greater affinity for oxygen than phosphorus has. Part of the metal therefore combines with¹²¹ the Phosphuret,

Tin.

the oxygen of the glass during the fusion, and flies off in the state of an oxide, and the rest of the tin combines with the phosphorus. The phosphuret of tin may be cut with a knife; it extends under the hammer, but separates in laminae. When newly cut it has the colour of silver; its filings resemble those of lead. When these filings are thrown on burning coals, the phosphorus takes fire. This phosphuret may likewise be formed by dropping phosphorus gradually into melted tin. According to Pelletier, to whose experiments we are indebted for the knowledge of all the phosphurets, it is composed of about 85 parts of tin and 15 of phosphorus*. Margraf also formed this phosphuret, but he was ignorant of its composition.

Tin does not seem capable of combining with carbon. It is capable of combining with most of the metals.

1. It mixes readily with gold by fusion; but the proportions in which these metals combine chemically are still unknown. When one part of tin and twelve of gold are melted together, the alloy is brittle, hard, and bad coloured. Twenty-four parts of gold and one of tin produce a pale coloured alloy, harder than gold, but possessed of considerable ductility. Gold alloyed with no more than $\frac{1}{7}$ th of tin is scarcely altered in its properties, according to Mr Alchorne†; but Mr Tillet, who has lately examined this alloy, found, that whenever it was heated it broke into a number of pieces.

2. The alloy of silver and tin is hardly known. According to Gellert and succeeding chemists, it is exceedingly brittle.

3. The alloy of platinum and tin is very fusible and brittle, at least when these metals are mixed in equal proportions‡.

4. Mercury dissolves tin very readily, by being poured on it when melted. This amalgam crystallizes in the form of cubes, according to Daubenton; but, according to Sage, in grey brilliant square plates, thin towards the edges, and attached to each other so that the cavities between them are polygonal. It is composed of three parts of mercury and one of tin. The amalgam of tin is used to silver the backs of glass mirrors.

5. Tin unites very readily with copper, and forms alloys known by the names of *bronze* and *bell-metal*. The proportions of the ingredients cannot easily be assigned, perhaps because the alloy has an affinity both for copper and tin. The specific gravity of the alloy in all proportions is greater than the mean specific gravity of the two metals separately. When the quantity of tin is small compared to that of the copper, $\frac{1}{5}$ th for instance, the alloy is called *bronze*: it is brittle, yellow, and much heavier than copper; much more fusible, and less liable to be altered by exposure to the air. It was this alloy which the ancients used for sharp-edged instruments before the method of working iron was brought to perfection. The χαλκος of the Greeks, and perhaps the *as* of the Romans, was nothing else. Even their copper coins contain a mixture of tin §.

6. Tin seems capable of being united to iron by fusion. That there is an affinity between these metals is evident from their adhesion when iron is dipped into melted tin. This is the method of making *tinplate*.

The affinities of tin, according to Bergman, are as follows:

Zinc,
Mercury,
Copper,
Antimony,
Gold,
Silver,
Lead,
Iron,
Manganese,
Nickel,
Arsenic,
Platinum,
Bismuth,
Cobalt,
Sulphuret of alkali,
Oxygen?
Sulphur?
Phosphorus?

SECT. VIII. Of Lead.

LEAD appears to have been very early known. It is mentioned several times by Moses. The ancients seem to have considered it as nearly related to tin.

Lead is of a bluish white colour, somewhat darker than tin. When newly melted it is very bright, but soon becomes tarnished by exposure to the air. It has scarcely any taste, but emits on friction a peculiar smell.

It is very malleable, and may be reduced to thin plates by the hammer; but its ductility is very imperfect: a wire of lead $\frac{1}{8}$ th of an inch in diameter is only capable of supporting a weight of 29 $\frac{1}{4}$ pounds*.

Its hardness is 5 †; its specific gravity is 11,3523 ‡. Its specific gravity is not increased by hammering, neither does it become harder, as is the case with other metals: a proof that the hardness which metals assume under the hammer is in consequence of an increase of density.

It melts, according to Dr Lewis, at 540° Fahrenheit; according to the Dijon academicians, at 549°. When exposed to a violent heat it evaporates completely.

When cooled slowly, after being fused, it crystallizes. The Abbé Mongez obtained it in quadrangular pyramids, lying on one of their sides. Each pyramid was composed as it were of three layers. Pajot obtained it in the form of a polyhedron with 32 sides, formed by the concurrence of six quadrangular pyramids §.

Lead stains paper or the fingers of a bluish black colour.

There is a strong affinity between this metal and oxygen. When nitric acid is poured upon it, an effervescence ensues, owing to the decomposition of the acid; the lead seizes oxygen from it, and is converted into a white powder, which may be obtained pure by evaporating it to dryness, and then washing it in pure water. This is the *white oxide of lead*. It is composed of about 95 parts of lead and five of oxygen ||. The affinities of this oxide are, according to Bergman, as follows:

Sulphuric acid,
Sebacic,
Saccholactic,
Oxalic,
Arsenic,
Tartarous,
Phosphoric,
Muriatic,

Benzoic,

* Ann. de Chim. xiii. 116.

122 Alloys,

† Alchorne, Phil. Transf.

‡ Dr Lewis, proportions †.

124 Properties of lead.

* Macquer's Dictionary. † Kirwan's Miner. ii. 202.

‡ Brisson.

§ Jour. de Phys. xxxviii. 53.

125 Its oxides.

|| Kirwan's Miner. ii. 499.

§ See Dizel's Analysis, Jour. de Phys. 1790.

123 And affinities of tin.

Lead.

- Benzoic (v) ?
- Sulphurous,
- Suberic ? } (v)
- Zoonic ? }
- Nitric,
- Pyromucous (v) ?
- Fluoric,
- Citric,
- Formic,
- Lactic,
- Acetous,
- Boracic,
- Prussic,
- Carbonic,
- Fixed alkali.

When lead is exposed to heat in contact with air, its surface is soon covered with a grey pellicle; when this is taken off, another soon forms: and in this manner the whole lead may soon be converted into a dirty grey powder, which seems to be the white oxide mixed with a little lead. When this powder is heated red hot, it assumes a deep yellow colour. This is the *yellow oxide* of lead, formerly called *massicot*. If the heat be continued, the colour is gradually changed to a beautiful red. This is the *red oxide of lead*, formerly called *minium*. It is composed, as Lavoisier has shewn, of 88 parts of lead and 12 of oxygen*.

Mem. Par. 1781.

The manner in which these changes are brought about is evident; the metal gradually absorbs oxygen from the atmosphere. This has been actually proved by experiment. These oxides (if they really differ in the proportion of oxygen) resemble acids in several of their properties. They are very easily converted into glass by fusion. Scheele has shewn that there is also a *brown oxide of lead*, which contains more oxygen than any of the others.

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Sulphuret,

Sulphur unites easily to lead by fusion. The sulphuret of lead is brittle, of a deep grey colour, and much less fusible than lead. These two substances are often found naturally combined; the compound is then called *galena*. Sulphuret of lead is composed, according to the experiments of Wenzel, of 868 parts of lead and 132

† Kirwan's Miner. ii. 492.

127 Phosphuret,

of sulphur †. Phosphuret of lead may be formed by mixing together equal parts of filings of lead and phosphoric glass, and fusing them in a crucible. It may be cut with a knife, but separates into plates when hammered. It is of a white silver colour with a shade of blue, but it soon tarnishes when exposed to the air. This phosphuret may also be formed by dropping phosphorus into melted lead. It is composed of about 12 parts of phosphorus and 88 of lead †.

‡ Pelletier, Ann. de Chim. xiii. 114.

128 Alloys, and

Lead combines with most of the other metals.
1. Little is known concerning the alloy of lead and gold. It is said to be brittle.

2. The alloy of silver and lead is very fusible, and neither elastic nor sonorous.

Lead.

3. Platinum and lead unite in a strong heat: the alloy is brittle, of a purplish colour, and soon changes on exposure to the air*.

* Fourcroy.

4. Mercury, when poured upon melted lead, dissolves it readily. The amalgam is white and brilliant, and assumes a solid form. It is capable of crystallizing. The crystals are composed of one part of lead and one and a half of mercury †.

† Dijon Académiciens.

5. Copper and lead combine easily by fusion; but the alloy has not been applied to any use.

6. Iron does not unite with lead.

7. Lead and tin may be combined by fusion. The alloy in the proportion of two parts of lead and one of tin is more soluble than either of the metals separately. It is accordingly used by plumbers as a solder.

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Lead, when taken internally, acts as a poison. Its affinities, according to Bergman, are as follows:

- Gold,
- Silver,
- Copper,
- Mercury,
- Bismuth,
- Tin,
- Antimony,
- Platinum,
- Arsenic,
- Zinc,
- Nickel,
- Iron,
- Sulphuret of alkali,
- Sulphur,
- Phosphorus ?

Affinities.

The ancients gave to the seven metals last described (omitting *platinum*, which they did not know) the names of the planets, and denoted each of them by particular marks, which represented both the planet and the metal.

130 Names and marks given to the metals by the ancients.

Gold	was the Sun,	and represented by ☉.
Silver	the Moon,	☾.
Mercury	Mercury,	♃.
Copper	Venus,	♀.
Iron	Mars,	♂.
Tin	Jupiter,	♃.
Lead	Saturn,	♄.

It seems most probable that these names were first given to the planets; and that the seven metals, the only ones then known, were supposed to have some relation to the planets or to the gods that inhabited them, as the number of both happened to be the same. It appears from a passage in Origen, that these names first arose among the Persians (w). Why each particular metal was denominated by a particular planet it is not easy to see. Many conjectures have been made, but scarcely any of them are satisfactory.

As

(v) Benzoat of lead is decomposed by muriatic acid. Trommsdorf, *Ann. de Chim.* xi. 317.
(v) Suberic acid decomposes nitrat of lead. See *Jameſon's Mineralogy*, p. 166. Zoonic acid produces the same effect, as Berthollet has observed.

(v) Schrickel places it after the three mineral acids.

(w) *Contra Celsum*, lib. vi. 22.—“ Celsus de quibusdam Perſarum myſteriis ſermonem facit. Harum rerum, inquit, aliquod reperitur in Perſarum doctrina Mithracique eorum myſteriis veſtigium. In illis enim duæ cæleſtes converſiones, alia ſtellarum fixarum, errantium alia, et animæ per eas tranſitus quodam ſymbolo repræſentantur, quod hujusmodi eſt. Scala altas portas habens, in ſumma autem octava porta. Prima portarum plumbea, altera ſtannea,

Part I.

Lead. 131 Origin of these marks according to the astrologers;

As to the characters by which these metals were expressed, astrologers seem to have considered them as the attributes of the deities of the same name. The circle in the earliest periods among the Egyptians was the symbol of divinity and perfection; and seems with great propriety to have been chosen by them as the character of the sun, especially as, when surrounded by small strokes projecting from its circumference, it may form some representation of the emission of rays. The semicircle is, in like manner, the image of the moon; the only one of the heavenly bodies that appears under that form to the naked eye. The character ♄ is supposed to represent the scythe of Saturn; ⚡ the thunderbolts of Jupiter; ♂ the lance of Mars, together with his shield; ♀ the looking-glass of Venus; and ☿ the caduceus or wand of Mercury.

132 According to the alchymists.

The alchymists, however, give a very different account of these symbols. Gold was the most perfect metal, and was therefore denoted by a circle. Silver approached nearest it; but as it was inferior, it was denoted only by a semicircle. In the character ☿ the adepts discovered gold with a silver colour. The cross at the bottom expressed the presence of a mysterious something, without which mercury would be silver or gold. This something is combined also with copper; the possible change of which into gold is expressed by the character ♀. The character ♂ declares the like honourable affinity also; though the semicircle is applied in a more concealed manner: for, according to the properest mode of writing, the point is wanting at the top, or the upright line ought only to touch the horizontal, and not to intersect it. Philosophical gold is concealed in steel; and on this account it produces such valuable medicines. Of tin, one half is silver, and the other consists of the unknown something; for this reason the cross with the half moon appears in ⚗. In lead this something is predominant, and a similitude is observed in it to silver. Hence in its character ♄ the cross stands at the top, and the silver character is only suspended on the right hand behind it.

133 Their real origin.

The fact, however, according to Professor Beckmann, from whom most of the above remarks have been taken, seems to be, that these characters are mere abbreviations of the old names of the planets.

* History of Inventions, English translation, iii. 67. "The character of Mars (he observes*), according to the oldest mode of representing it, is evidently an abbreviation of the word ζυρος, under which the Greek mathematicians under-

stood that deity; or, in other words, the first letter ζ, with the last letter ς placed above it. The character of Jupiter was originally the initial letter of Ζεϋς; and in the oldest manuscripts of the mathematical and astrological works of Julius Firmicus, the capital Ζ only is used, to which the last letter ς was afterwards added at the bottom, to render the abbreviation more distinct. The supposed looking-glass of Venus is nothing else than the initial letter distorted a little of the word Φασηρις, which was the name of that goddess. The imaginary scythe of Saturn has been gradually formed from the two first letters of his name Κρανος, which transcribers, for the sake of dispatch, made always more convenient for use, but at the same time less perceptible. To discover in the pretended caduceus of Mercury the initial letter of his Greek name Στλαρον, one needs only look at the abbreviations in the oldest manuscripts, where they will find that the σ was once written as C; they will remark also, that transcribers, to distinguish this abbreviation from the rest still more, placed the C thus O, and added under it the next letter τ. If those to whom this deduction appears improbable will only take the trouble to look at other Greek abbreviations, they will find many that differ still farther from the original letters they express than the present character ☿ from the C and τ united. It is possible also that later transcribers, to whom the origin of this abbreviation was not known, may have endeavoured to give it a greater resemblance to the caduceus of mercury. In short, it cannot be denied that many other astronomical characters are real symbols, or a kind of proper hieroglyphics, that represent certain attributes or circumstances, like the characters of Aries, Leo, and others quoted by Saumaise."

SECT. IX. Of Zinc.

THE ancients were acquainted with a mineral to which they gave the name of Cadmea, from Cadmus, who first taught the Greeks to use it. They knew that when melted with copper it formed brass; and that when burnt, a white spongy kind of ashes was volatilised; which they used in medicine*. This mineral contained a good deal of zinc; and yet there is no proof remaining that the ancients were acquainted with that metal (x). It is first mentioned in the writings of Albertus Magnus, who died in 1280: but whether he had seen it is not so clear, as he gives it the name of *marcasite of gold*, which implies, one would think, that it had

134 Discovery of zinc. * Pliny, l. 34. c. 2. and 10.

stannea, tertia ex ære, quarta ferrea, quinta ex ære mixto, sexta argentea, septima ex auro. Κλιμαξ ὑψηλοῦς, ἐπι δ' αὐτῇ πύλη οὐδὼν. Ἡ πρώτη τῶν πυλῶν μολιβδου, ἡ δευτέρα κασσιτέρου, ἡ τρίτη χαλκοῦ, ἡ τετάρτη σιδήρου, ἡ πέμπτη καρασοῦ νομισματός. ἡ ἕκτη ἀργυροῦ, χρυσοῦ δ' ἡ ἕβδομη. Primum assignant Saturno tarditatem illius sideris plumbo indicantes: alteram Veneri, quam referunt, ut ipsi quidem putant, stanni splendor et mollities; tertiam Jovi, aheneam illam quidem et solidam: quartam Mercurio, quia Mercurius et ferrum, uterque operum omnium tolerantes, ad mercaturam utiles, laborum patientissimi. Marti quintam, inæqualem illam et variam propter mixturam. Sextam, quæ argentea est, lunæ; septimam auream soli tribuunt, quia solis et lunæ colores hæc duo metalla referunt."

Borrichius suspects, with a good deal of probability, that the names of the gods in this passage have been transposed by transcribers, either through ignorance or design. He arranges them as follows: "Secundam portam faciunt Jovis, comparantes ei stanni splendorem et mollitiam; tertiam Veneris æratam et solidam; quartam Martis, est enim laborum patiens, æque ac ferrum, celebratus hominibus; quintam Mercurii propter mixturam inæqualem ac variam, et quia negotiator est; sextam Lunæ argenteam; septimam Solis auream." *Ol. Borrichius de ortu et progressu chemiæ.* Hafniæ, 1668, 4to, p. 29.

(x) Grignon indeed says, that something like it was discovered in the ruins of an ancient Roman city in Champagne; but the substance which he took for it was not examined with any accuracy. It is impossible, therefore to draw any inference whatever from his assertion. *Bulletin des fouilles d'une ville Romaine*, p. 11.

had a yellow colour (r). The word *zinc* occurs first in the writings of Paracelsus, who died in 1541. He informs us very gravely, that it is a metal, and not a metal, and that it consists chiefly of the ashes of copper*. This metal has also been called *spelter*.

Zinc has never been found in Europe in a state of purity, and it was long before a method was discovered of extracting it from its ore (z). Henkel pointed out one in 1721, and Von Swab obtained it by distillation in 1742, and Margraf published a process in the Berlin Memoirs in 1746†.

It is of a bluish white colour, somewhat lighter than lead. It has neither taste nor smell.

It has some degree of malleability; for by compression it may be reduced into thin plates ‡; but it cannot be drawn out into wire. It is more brittle when hot than when cold.

Its hardness is 6 $\frac{1}{2}$. Its specific gravity, when compressed, is 7,1908 ||; in its usual state, 6,862 ¶. It melts at about 699° Fahrenheit*.

When allowed to cool slowly, it crystallizes in small bundles of quadrangular prisms, disposed in all directions. If they are exposed to the air while hot, they assume a blue changeable colour †.

When zinc is kept melted in contact with air, it becomes covered with a grey pellicle, which gradually assumes a yellowish tint. By removing this pellicle from time to time, the whole of the metal may be reduced into a grey powder. This is the *grey oxide of zinc*. This oxide is probably composed of about 85 parts of zinc and 15 of oxygen ‡. When zinc is violently heated, it burns with a bright white flame, and at the same time a quantity of very light white flakes are sublimed. These flakes are the *white oxide of zinc*, which contains a good deal more oxygen than the grey oxide (A).

Zinc may also be oxidated by solution in acids, particularly the nitric acid. Whether the oxide obtained by precipitating zinc from its solution in that acid, or by distilling that acid off zinc, be really different from the white oxide, has not yet been properly ascertained;

but one would be apt to suspect, from the experiments mentioned by Mr Kirwan, that it contained a good deal more oxygen*.

The affinities of the oxides, or rather of the white oxide of zinc, are, according to Bergman, as follows:

Oxalic acid,
Sulphuric,
Pyromucous †,
Muriatic,
Saccholactic,
Nitric,
Sebacic,
Tartaric,
Phosphoric,
Citric,
Succinic,
Fluoric,
Arsenic,
Formic,
Lactic,
Acetous,
Boracic,
Prussic,
Carbonic,
Ammonia.

† *Schwickel*.

There is an affinity between sulphur and zinc, as is evident from these two substances being often found united; but it is very difficult to form the sulphuret of zinc artificially, on account of the rapid oxidation and consequent volatilization of the zinc. Morveau, however, succeeded in forming it.

Zinc may be combined with phosphorus, by dropping small bits of phosphorus into it while in a state of fusion. Pelletier, to whom we are indebted for the experiment, added also a little resin, to prevent the oxidation of the zinc. Phosphuret of zinc is of a white colour, a metallic splendor, but resembles lead more than zinc. It is somewhat malleable. When hammered or filed, it emits the odour of phosphorus. When exposed to a strong heat, it burns like zinc †.

Phosphorus

(r) The passages in which he mentions it are as follows:—*De Mineral. lib. ii. cap. 11.* “*Marchasita, five marchasida ut quidam dicunt, est lapis in substantia, et habet multas species, quare colorem accipit cujuslibet metalli, et sic dicitur marchasita argentea et aurea, et sic dicitur aliis. Metallum tamen quod colorat eum non distillat ab ipso, sed evaporat in ignem, et sic relinquitur cinis inutilis, et hic lapis notus est apud alchimicos, et in multis locis veniuntur.*”

Lib. iii. cap. 10. “*Æs autem invenitur in venis lapidis, et quod est apud locum qui dicitur Gofelaria est purissimum et optimum, et tota substantia lapidis incorporatum, ita quod totus lapis est sicut marchasita aurea, et profundatum est melius ex eo quod purius.*”

Lib. v. cap. 5. “*Dicimus igitur quod marchasita duplicem habet in sui creatione substantiam, argenti vivi scilicet mortificati, et ad fixationem approximantis, et sulphuris adurentis. Ipsam habere sulphureitatem comperimus manifesta experientia. Nam cum sublimatur, ex illa emanat substantia sulphurea manifesta comburens. Et sine sublimatione similiter penditur illius sulphureitas.*”

“*Nam si ponatur ad ignitionem, non suscipit illam priusquam inflammatione sulphuris inflammetur, et ardeat. Ipsam vero argenti vivi substantiam manifestatur habere sensibilibiter. Nam albedinem præstat Veneri meri argenti, quemadmodum et ipsum argentum vivum, et colorem in ipsius sublimatione cælestium præstare, et luciditatem manifestam metallicam habere vidimus, quæ certum reddunt artificem Alchimicæ, illam has substantias continere in radice sua.*”

(z) The real discoverer of this method appears to have been Dr Isaac Lawfon. See *Pott, III. Diff. 7.* and *Watson's Chemical Essays.*

(A) Pott observed, that it was $\frac{1}{10}$ th heavier than the zinc from which it was obtained; and Mr Boyle had long before ascertained the same fact.—*Shaw's Boyle, II. 391, 394.*

This oxide of zinc was well known to the ancients. Dioscorides describes the method of preparing it. The ancients called it *pompholyx*, the early chemists gave it the name of *lana philosophica*. Dioscorides compares it to wool,

ἰριον πολυπαις ἀρομοιονται, v. 85. p. 352.

Zinc.
* *Mineral,*
ii. 499.

137
Sulphuret,

138
Phospho-
rets,

† *Ann. de*
Chim. xiii.
129.

247
See Vol.
of his
Works
410.

† *Bergman,*
ii. 509.
155
Properties
of zinc.
† *Sage.*

§ *Kirwan's*
Miner. ii.
232
|| *Briffon.*
¶ *Kirwan,*
ibid.
* *Bergman.*
† *Mongez.*
36
Its oxides,

† *Morveau,*
Kirwan's
Miner. ii.
489.

Zinc.

Phosphorus combines also with the oxide of zinc, a compound which Margraf had obtained, during his experiments on phosphorus. When 12 parts of oxide of zinc, 12 parts of phosphoric glass, and two parts of charcoal powder, are distilled in an earthen ware retort, and a strong heat applied, a metallic substance sublimes of a silver-white colour, which, when broken, has a vitreous appearance. This, according to Pelletier, is phosphuret of oxide of zinc. When heated by the blow-pipe, the phosphorus burns, and leaves behind a glass transparent while in fusion, but opaque after cooling*.

* Pelletier, *ibid.* 128.
139
Carburet,

Zinc also combines with carbon, and forms carburet of zinc. The French chemists have shewn that zinc generally contains some carbon.

Zinc combines with most of the metals :

140
Alloys,

1. It mixes with gold in any proportion. The alloy is the whiter and the more brittle the greater quantity of zinc it contains. An alloy, consisting of equal parts of these metals, is very hard and white, receives a fine polish, and does not tarnish readily. It has therefore been proposed by Mr Malouin† as very proper for the specula of telescopes. One part of zinc is said to destroy the ductility of 100 parts of gold ‡.

† Mem. Acad. Par. 1742.
‡ Kirwan's *Macquer's Dictionary*.

2. The alloy of silver and zinc is easily produced by fusion. It is brittle.

3. Platinum combines very readily with zinc. The alloy is brittle, pretty hard, very fusible, and of a bluish white colour, not so clear as that of zinc §.

§ Dr Lewis.

4. Zinc may be combined with mercury by fusion. The amalgam is solid. It crystallizes when melted and cooled slowly into lamellated hexagonal figures, with cavities between them. They are composed of one part of zinc and two and a half of mercury ||. It is used to rub on electrical machines, in order to excite electricity.

|| *Elements de Chim. Dijon*, t. 3.

5. Zinc combines very readily with copper. This alloy, which is called *brass*, was known to the ancients. They used an ore of zinc to form it, which they called *cadmia*. This alloy was very much valued by the ancients. Dr Watson has proved that it was brass which they gave the name of *orichalcum* ¶. Their *æs* was copper or rather bronze (B). Brass is composed of about three parts of copper and one of zinc. It is of a beautiful yellow colour, more fusible than copper, and not so apt to tarnish. It is malleable, and so ductile that it may be drawn out into wire. When the alloy contains three parts of zinc and four of copper, it assumes a colour nearly the same with gold, but it is not so malleable as brass. It is then called *pinchbeck*, *prince's metal*, or *Prince Rupert's metal*.

¶ *Manchester Trans.* vol. ii.

6. The alloy of iron and zinc has scarcely been examined : but Malouin has shewn that zinc may be used

instead of tin to cover iron plates ; a proof that there is an affinity between the two metals*.

Antimony.

7. Tin and zinc combine easily. The alloy is harder than tin. This alloy is often the principal ingredient in the compound called *peawter*.

* Mem. Par. 1742.

8. Mr Gmelin has succeeded in forming an alloy of zinc and lead by fusion. He put some suet into the mixture, and covered the crucible, in order to prevent the evaporation of the zinc. When the zinc exceeded the lead very much, the alloy was malleable, and much harder than lead. A mixture of two parts of zinc and one of lead formed an alloy more ductile and harder than the last. A mixture of equal parts of zinc and lead formed an alloy differing little in ductility and colour from lead ; but it was harder, and more susceptible of polish, and much more sonorous. When the mixture contained a smaller quantity of zinc, it still approached nearer the ductility and colour of lead, but it continued harder, more sonorous, and susceptible of polish, till the proportions approached to one of zinc and 16 of lead, when the alloy differed from the last metal only in being somewhat harder †.

The affinities of zinc, according to Bergman, are as follows :

† *Ann. de Chim.* ix. 95.

Copper,
Antimony,
Tin,
Mercury,
Silver,
Gold,
Cobalt,
Arsenic,
Platinum,
Bismuth,
Lead,
Nickel,
Iron.

141
And affinities.

SECT. X. Of Antimony.

THE ancients were acquainted with an oxide of antimony to which they gave the names of *στυμ* and *stibium*. Pliny † informs us that it was found in silver ore ; and we know that at present there are silver ores § in which it is contained. It was used as an external application to sore eyes ; and Pliny gives us the method of preparing it ||. Galen supposes that the *τετραγρον* of Hippocrates ¶ was a preparation of antimony ; but this wants proof. It does not appear, however, that the ancients considered this substance as a metal, or that they knew antimony in a state of purity (c). Who first extracted it from its ore we do not know ; but Basil Valentine, a chemist of the 16th century, is the first who describes the process.

† Pliny, l. xxxiii. c. 6.
§ Kirwan's *Miner.* ii. 110.
|| Pliny, *ibid.* 142.
¶ Discovery of Antimony.

H h

process.

(B) The ancients do not seem to have known accurately the difference between copper, brass, and bronze Hence the confusion observable in their names. They considered brass as only a more valuable kind of copper, and therefore often used the word *æs* indifferently to denote either. It was not till a late period that mineralogists began to make the distinction. They called copper *æs cyprium*, and afterwards only *cyprium*, which in process of time was converted into *cuprum*. When these changes took place is not known accurately. Pliny uses *cyprium*, lib. xxxvi. c. 26. The word *cuprum* occurs first in Spartian, who lived about the year 290. He says in his life of Caracalla, *cancelli ex are vel cupro*.

(c) Mr Roux indeed, who at the request of Count Caylus analysed an ancient mirror, found it composed of copper, lead, and antimony. This would go far to convince us that the ancients knew this metal, provided it could be proved that the mirror was really an ancient one ; but this point appears to be extremely doubtful.

Antimony. process. To him indeed we are indebted for our acquaintance with many of the properties of this metal.

Antimony is of a white colour, with a shade of grey.

* *Fourcroy.* It has a sensible taste, but no smell *.

¹⁴³ Properties of antimony. It is neither malleable nor ductile, but exceedingly brittle. Its specific gravity, according to *Briffon*, is 6,702; according to *Bergman*, 6,860. Its hardness is 6,5 †. It melts at 809° Fahrenheit ‡. If after this the heat be increased, the metal evaporates. On cooling it assumes the form of oblong crystals, perpendicular to the internal surface of the vessel in which it cools. It is to this crystallization that the laminated structure which antimony always assumes is owing.

Neither air nor water have much effect on this metal.

¹⁴⁴ Its oxides. When antimony is beat to powder, and exposed for some time to a gentle heat, it absorbs oxygen, and is converted into a grey powder. This is the *grey oxide of antimony*. When this metal is kept for some time melted in contact with air, it sublimes in the form of a white powder, formerly called *snow* or *white flowers of antimony*. This is the *white oxide of antimony*. This oxide may be procured also by pouring nitric acid on antimony, and then evaporating to dryness. Antimony attracts the oxygen from the acid, and thus passes very rapidly into the state of an oxide. This oxide seems to consist of about 77 parts of antimony and 23 of oxygen §. The nature of these oxides has never yet been accurately inquired into. It is not even known at present whether the white oxide obtained by heat and that obtained by nitric acid contain the same quantity of oxygen. The experiments mentioned by *Mr Kirwan* make the contrary probable ||; and yet these oxides have too many qualities in common to render these experiments conclusive. The white oxide of antimony is soluble in water ¶; and when fused, is converted into a transparent glass. The white oxide obtained by nitric acid seems to possess many of the properties of an acid.

The affinities of the grey oxide of antimony are, according to *Bergman*, as follows:

- Sebacic acid,
- Muriatic,
- Benzoic (D) ?
- Oxalic,
- Sulphuric,
- Pyromucous *,
- Nitric,
- Tartarous,
- Saccholarctic,
- Phosphoric,
- Citric,
- Succinic,
- Fluoric,
- Arsenic,
- Formic,
- Lactic,
- Acetous,
- Boracic,
- Prussic,
- Carbonic.

¹⁴⁵ Sulphurets. Sulphur combines readily with antimony. This compound is often found native: it was formerly called antimony, and the pure metal was then called *regulus of*

antimony. Sulphuret of antimony is easily melted by a moderate heat: if the heat be continued, the sulphur sublimes, and at the same time the antimony absorbs oxygen, and is converted into a grey oxide. This sulphuret is composed of 74 parts of antimony and 26 of sulphur *.

The grey oxide of antimony is also capable of combining with about $\frac{1}{8}$ of sulphur. This compound, by fusion, may be converted into glass. It was formerly used in medicine under the name of *glass of antimony*.

When equal parts of antimony and phosphoric glass are mixed together with a little charcoal powder, and melted in a crucible, phosphuret of antimony is produced. It is of a white colour, brittle, appears laminated when broken, and at the fracture there appear a number of small cubic facets. When melted it emits a green flame, and then sublimes in the form of a white powder. Phosphuret of antimony may likewise be prepared by fusing equal parts of antimony and phosphoric glass, or by dropping phosphorus into melted antimony †.

Antimony is capable of combining with most of the metals

1. Gold may be alloyed with antimony by fusing them together. The antimony is afterwards separable by an intense heat. This alloy is little known, and has never been applied to any use.

2. The alloy of silver and antimony is brittle, and its specific gravity, as *Gellert* has observed, is greater than intermediate between the specific gravities of the two metals which enter into it.

3. Platinum easily combines with antimony. The alloy is brittle, and much lighter than platinum ‡. The antimony cannot afterwards be completely separated by heat.

4. Mercury does not easily combine with antimony. *Mr Gellert* succeeded in amalgamating this metal by putting it into hot mercury, and covering the whole with water.

5. Copper combines readily with antimony by fusion. The alloy is of a beautiful violet colour, and its specific gravity is greater than intermediate §.

6. Iron combines with antimony, and forms a brittle hard alloy, the specific gravity of which is less than intermediate. The magnetic quality of iron is much more diminished by being alloyed with antimony than with any other metal ||.

7. The alloy of tin and antimony is white and brittle; its specific gravity is less than intermediate ¶.

8. When equal quantities of lead and antimony are fused, the alloy is porous and brittle: three parts of lead and one of antimony form a compact alloy, malleable, and much harder than lead: 12 parts of lead and one of antimony form an alloy very malleable, and a good deal harder than lead: 16 parts of lead and one of antimony form an alloy which does not differ from lead except in hardness *. This alloy forms printers types.

9. Zinc and antimony form a brittle alloy, the specific gravity of which is less than intermediate †. The alloys of antimony are little known. *Gellert* is almost the only person who has examined them. It would require a great number of experiments to be able to fix the proportions of their ingredients.

The

(D) Muriatic acid decomposes benzoat of antimony. *Trommsdorf, Ann. de Chim. xi. 317.*

The affinities of antimony are, according to Bergman, as follows :

Iron,
Copper,
Tin,
Lead,
Nickel,
Silver,
Bismuth,
Zinc,
Gold,
Platinum,
Mercury,
Arsenic,
Cobalt,
Sulphuret of arsenic,
Sulphur,
Phosphorus?

Formic,
Lactic,
Acetous,
Prussic,
Carbonic,
Ammonia.

SECT. XI. *Of Bismuth.*

THE ancients appear to have known nothing of bismuth, nor do we know who discovered it; but it is first mentioned by George Agricola, who was born about the end of the 15th century.

¹⁴⁸ Properties of bismuth. Bismuth is of a yellowish or reddish white colour, and almost destitute both of taste and smell.

* *Kirwan*. It is brittle. Its hardness is 6*. Its specific gravity is 9,8227†. It melts at 460° Fahrenheit‡.

† *Briffon*. When heated in close vessels, it sublimes. When allowed to cool slowly after fusion, it crystallizes.

Bismuth is not altered by water. When exposed to the air it soon tarnishes.

¹⁴⁹ Its oxides, When bismuth is kept fused in contact with air, it is gradually oxidated. When heated red hot, it emits a very faint blue flame, and its oxide evaporates in the form of a yellowish smoke. When this smoke is collected, it is found to consist of a brown-coloured powder. This is the *brown oxide of bismuth*. It is composed of about 94 parts of bismuth and 6 of oxygen§. Bismuth decomposes nitric acid with great rapidity, by attracting its oxygen. If the quantity of acid be considerable, it dissolves the oxide as it forms; but the greater part of it may be precipitated by diluting the acid with water. This precipitate, which is a white powder, is *white oxide of bismuth*. It is composed of about 84 parts bismuth and 16 of oxygen||.

§ *Kirwan's Miner. ii.* 489.

|| *Ibid.*

The affinities of the oxides of bismuth are, according to Bergman, as follows :

Oxalic acid,
Arsenic,
Tartarous,
Phosphoric,
Sulphuric,
Sebacic,
Muriatic,
Benzoic (E)?
Nitric,
Fluoric,
Saccholarctic,
Succinic,
Citric,

Sulphur combines readily with bismuth by fusion. The sulphuret of bismuth is of a bluish grey colour, and crystallizes into beautiful tetrahedral needles. It is composed of 85 parts of bismuth and 15 of sulphur*.

There appears to be little affinity between bismuth and phosphorus. Mr Pelletier attempted to produce the phosphuret of bismuth by various methods without success. When he dropped phosphorus, however, into bismuth in fusion, he obtained a substance which did not apparently differ from bismuth, but which, when exposed to the blow-pipe, gave evident signs of containing phosphorus. Phosphuret of bismuth, according to Pelletier, is composed of about 96 parts of bismuth and four of phosphorus†.

Bismuth combines readily with most of the metals.

1. Equal parts of bismuth and gold form a brittle alloy, nearly of the same colour with bismuth‡.

2. Equal parts of bismuth and silver form also a brittle alloy, but less so than the last. The specific gravity of both these is greater than intermediate§.

3. The alloy of bismuth and platinum is also very brittle. When exposed to the air it assumes a purple, violet, or blue colour. The bismuth may be separated by heat||.

4. Mercury dissolves bismuth very easily. The amalgam is more fluid than pure mercury, and has the property of dissolving lead and rendering it also fluid¶. It is capable, however, of crystallizing. The crystals are either octahedrons, lamellated triangles, or hexagons. They are composed of one part of bismuth and two of mercury*.

5. The alloy of copper and bismuth is not so red as copper.

6. Nothing is known concerning the alloy of iron and bismuth.

7. Bismuth and tin unite readily. A small portion of bismuth increases the brightness, hardness, and sonorousness of tin: it often therefore enters into the composition of the compound called *peawter*. Equal parts of tin and bismuth form an alloy that melts at 280°: eight parts of tin and one of bismuth, melt at 390°: two parts of tin and one of bismuth, at 330°†.

8. The alloy of lead and bismuth is of a dark grey colour, a close grain, but very brittle.

9. Bismuth does not combine with zinc.

10. The alloy of antimony and bismuth is unknown. Bismuth likewise enters into triple compounds with metals: Two parts of lead, three of tin, and five of bismuth, form an alloy which melts at the heat of boiling water, which is 212°.

The affinities of bismuth, according to Bergman, are as follows :

Lead,
Silver,
Gold,

H h 2

Mercury,

Mercury,
Antimony,
Tin,
Copper,
Platinum,
Nickel,
Iron,
Sulphuret of alkali,
Sulphur,
Phosphorus?

Muriatic acid,
Oxalic,
Sulphuric,
Nitric,
Sebacic,
Tartarous,
Phosphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Arsenic,
Acetous,
Pruffic,
Ammonia,
Water,
Alcohol?

SECT XII. *Of Arsenic.*

THE word *arsenic* (*αρσενικον*) occurs first in the works of Dioscorides, and of some other authors who wrote about the beginning of the Christian era. It denotes in their works the same substance which Aristotle had called *σαινδαραχη* (F), and his disciple Theophrastus *αρσενικον*, which is a reddish coloured mineral, composed of arsenic and sulphur, used by the ancients in painting, and as a medicine.

The *white oxide of arsenic*, or what is known in commerce by the name of arsenic, is mentioned by Avicenna in the 11th century; but at what period the metal called *arsenic* was first extracted from that oxide is unknown. Paracelsus seems to have known it. It is mentioned by Schroeder in his *Pharmacopœia* published in 1649*.

Arsenic, when pure, is of a bluish white colour. It is exceedingly brittle. Its hardness is 7†. Its specific gravity 8,310‡.

When exposed to the temperature of 354° in close vessels it sublimes §, and crystallizes in regular tetrahedrons.

It is not much altered by water. Boiling water, however, is capable of dissolving, and retaining $\frac{1}{1000}$ of arsenic; but that part of the metal is no doubt reduced to the state of an oxide ||.

When arsenic is exposed to the open air, it very soon loses its lustre, and is gradually converted into a greyish black substance by combining with oxygen. This is called the *grey oxide of arsenic*.

When exposed to a moderate heat in contact with air, it sublimes in the form of a white powder, and at the same time emits a smell resembling garlic. If the heat be increased, it burns with an obscure bluish flame. This sublimate is *white oxide of arsenic*, which is composed of 93 parts of arsenic and 7 of oxygen ¶.

It is of a sharp acrid taste, which at last leaves an impression of sweetness, and is one of the most virulent poisons known. It has an alliaceous smell. It is soluble in 80 parts of water at the temperature of 60°, and in 15 parts of boiling water*. When this solution is evaporated, the oxide crystallizes †. When heated to 283°, it sublimes: if heat be applied in close vessels, it becomes pellucid like glass, but when exposed to the air it soon recovers its former appearance. The specific gravity of this glass is 5,000; that of the white oxide, 3,706 ‡.

This oxide is capable of combining with most of the metals, and in general renders them brittle. Its affinities, according to Bergman, are as follows:

Arsenic, or rather the white oxide of arsenic, is capable of combining with an additional dose of oxygen. The compound produced is *arsenic acid*, first discovered by Scheele, which contains 91 parts of arsenic and 9 of oxygen*.

Arsenic combines readily with sulphur. When heat is applied to a mixture of white oxide of arsenic and sulphur, the oxide is decomposed, part of the sulphur combines with its oxygen, and the remainder unites with the reduced metal. The sulphuret of arsenic produced by this process is of a yellow colour, and was formerly called *orpiment*. It is composed, according to Westrum, of 20 parts of arsenic and 80 of sulphur †. It is often found native. If a stronger heat be applied, so as to melt the sulphuret, it assumes a scarlet colour, and is much less volatile than formerly. This new compound was formerly called *realgar*. It is composed, according to Westrum, of 80 parts of arsenic and 20 of sulphur ‡. The difference therefore between it and orpiment is evident. During the fusion part of the sulphur without doubt sublimes. It might be called *red sulphuret of arsenic*.

Arsenic combines readily with phosphorus. The phosphuret of arsenic may be formed by distilling equal parts of its ingredients over a moderate fire. It is black and brilliant, and ought to be preserved in water. It may be formed likewise by putting equal parts of phosphorus and arsenic into a sufficient quantity of water, and keeping the mixture moderately hot for some time §.

Arsenic unites with most metals, and in general renders them more brittle and more fusible.

1. Melted gold takes up $\frac{1}{100}$ of arsenic ||. The alloy is brittle and pale.
2. Melted silver takes up $\frac{1}{12}$ of arsenic ¶. The alloy is brittle.
3. The alloy of platinum and arsenic is brittle and very fusible. It was first formed by Scheffer. The arsenic may be separated by heat.
4. The amalgam of arsenic is composed of five parts of mercury and one of arsenic*.
5. Copper takes up $\frac{1}{2}$ of arsenic †. This alloy is white;

* Bergman, ii. 278.

† Kirwan's *Miner.* ii. 254.

‡ Bergman, ii. 278.

§ *Ibid.*

¶ *Ibid.*

|| *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

¶ *Ibid.*

Part I.

Cobalt. white; and when the quantity of arsenic contained in it is small, both ductile and malleable*. It is called * Gellert. white tombac.

† Bergman, Ann de Chim. xiii. 139. 6. Iron is capable of combining with more than its own weight of arsenic †. This alloy is white, brittle, and capable of crystallizing. It is found native †.

‡ Kirwan's Miner. ii. 256. 7. The alloy of tin and arsenic is harder and more sonorous than tin, and has much resemblance externally to zinc. Tin often contains a small quantity of arsenic.

§ Bergman, Ibid. 8. Lead takes up 1/5th of arsenic §. The alloy is brittle and dark coloured.

|| Ibid. 158. 9. Zinc takes up 1/3th of arsenic, antimony 1/4th, and bismuth 1/3th ||.

And affinities. The affinities of arsenic, according to Bergman, are as follows:

- Nickel,
- Cobalt,
- Copper,
- Iron,
- Silver,
- Tin,
- Gold,
- Platinum,
- Zinc,
- Antimony,
- Sulphuret of alkali,
- Sulphur,
- Phosphorus.

SECT. XIII. Of Cobalt.

A MINERAL called cobalt (G), of a grey colour, and very heavy, has been used in different parts of Europe since the 15th century to tinge glass of a blue colour. From this mineral Brandt obtained in 1733 a new metal, to which he gave the name of cobalt ¶.

Cobalt is of a white colour, inclining to a bluish or steel grey. When pure, it is somewhat malleable while red hot*. Its hardness is 8 †. Its specific gravity is 8,15 (H). It requires for fusion a heat at least as great † Kirwan's as cast iron, which melts at 130° Wedgewood. No heat has been produced great enough to volatilize it ‡.

§ Bergman, Cobalt, when pure, does not seem to be affected by air or water.

It is attracted by the magnet.

It is not oxidated by heat without very great difficulty; but it has the property of decomposing nitric acid, and of attracting oxygen by that means with great rapidity.

The oxide of cobalt is of so deep a blue as to appear black. The oxide procured by heat is composed of 88 parts of cobalt and 12 of oxygen; that by nitric acid contains about 77 parts of cobalt and 23 of oxygen*. Its affinities, according to Bergman, are as follows:

- Oxalic acid,
- Muriatic,
- Sulphuric,
- Tartarous,
- Nitric,
- Sebacic,
- Phosphoric,
- Fluoric,
- Saccholarctic,
- Succinic,
- Citric,
- Formic,
- Lactic,
- Acetous,
- Arsenic,
- Boracic,
- Prussic,
- Carbonic,
- Ammonia.

The sulphuret of cobalt is not formed without difficulty. It is scarcely known.

Phosphuret of cobalt may be formed by heating the metal red hot, and then gradually dropping in small bits of phosphorus. It contains about 1/12th of phosphorus. It is white and brittle, and when exposed to the air soon loses its metallic lustre. The phosphorus is separated by heat, and the cobalt is at the same time oxidated. This phosphuret is much more fusible than pure cobalt †.

The combinations of cobalt with other metals have been very little examined into.

1. The alloy of gold and cobalt is not known.
2. Cobalt does not combine with silver by fusion †; but, according to Gellert, the alloy of silver and cobalt may be formed: it is brittle and of a grey colour §.
3. The alloy of platinum and cobalt is unknown.
4. Mer-

(G) The word cobalt seems to be derived from cobalus, which was the name of a spirit that, according to the superstitious notions of the times, haunted mines, destroyed the labours of the miners, and often gave them a great deal of unnecessary trouble. The miners probably gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes, and rendering their labour often fruitless; for as it was not known at first to what use the mineral could be applied, it was thrown aside as useless. It was once customary in Germany to introduce into the church-service a prayer that God would preserve miners and their works from kobalts and spirits. See Beckmann's History of Inventions, II. 362.

Mathesius, in his tenth sermon, where he speaks of cadmia fossilis (probably cobalt ore), says, "Ye miners call it kobolt; the Germans call the black devil and the old devil's whores and hags, old and black kobel, which, by their witchcraft do injury to people and to their cattle."

Lehmann, Paw, Delaval, and several other philosophers, have supposed that smalt (oxide of cobalt melted with glass and pounded) was known to the ancients, and used to tinge the beautiful blue glass still visible in some of their works; but we learn from Gmelin, who analysed some of these pieces of glass, that they owed their blue colour, not to the presence of cobalt but of iron.

According to Lehmann, cobalt ore was first used to tinge glass blue by Christopher Schurer, a glass-maker at Platten, about the year 1540.

(H) Berg. II. 231. According to Brisson, 7,8119.

¶ Ag. Up. fal. 1733. 159. Properties of cobalt, * Leonardi. 8, 15 (H). † Kirwan's Miner. ii. 268. ‡ Bergman, iv.

Cobalt. 160. Its oxides, 161. Sulphuret, 162. Phosphuret, 163. Pelletier's, Ann. de Chim. xiii. 134. 163. All'ys, Bergman's † Bergman's Elct. Attract. § Metallur. Chim.

- Nickel.
4. Mercury does not appear to amalgamate with cobalt.
 5. The alloy of copper and cobalt is scarcely known.
 6. The alloy of iron and cobalt is very hard, and not easily broken. Cobalt generally contains some iron, from which it is with great difficulty separated.
 7. The alloy of tin and cobalt is of a light violet colour.
 8. Cobalt does not combine with lead by fusion.
 9. The alloy of zinc and cobalt is not formed without difficulty.
 10. The alloy of antimony and cobalt is unknown.
 11. Cobalt does not combine with bismuth by fusion*.

* Baumé.

† Bergman,

iv.

164
And affinities.

12. Arsenic combines very readily with cobalt. The alloy is brittle, much more fusible, and more easily oxidated than pure cobalt †.

The affinities of cobalt are as follows :

Iron,
Nickel,
Arsenic,
Copper,
Gold,
Platinum,
Tin,
Antimony,
Zinc,
Sulphuret of alkali,
Sulphur,
Phosphorus?

SECT. XIV. *Of Nickel.*

A HEAVY mineral of a red colour is met with in several parts of Germany, which bears a strong resemblance to an ore of copper; but none of that metal can be extracted from it: for this reason the Germans called it *kupfer nickel* (devil's copper). Hierne mentioned it in 1694. Cronstedt was the first chemist who examined it with accuracy. He concluded from his experiments, which were published in the Stockholm Transactions for 1751 and 1754, that it contained a new metal, to which he gave the name of *nickel*.

165
Discovery of nickel,

Some chemists, particularly Mr Sage, affirmed, that it contained no new metal, but merely a compound of various known metals, which could be separated from each other by the usual processes. These assertions induced Bergman to undertake a very laborious course of experiments, in order if possible to obtain *nickel* in a state of purity: for Cronstedt had not been able to separate a quantity of arsenic, cobalt, and iron, which adhered to it with much obstinacy. These experiments have been very fully detailed in the article CHEMISTRY, in the *Encycl.* to which he begs leave to refer. Bergman has shewn, that nickel possesses peculiar properties, and that it can neither be reduced to any other metal, nor formed artificially by any combination of metals. It must therefore be considered as a peculiar metal. It may possibly be a compound, and so may likewise many other metals; but we must admit every thing to be a peculiar body which has peculiar properties, and we must admit every body to be simple till some proof be actually produced that it is a compound; otherwise we forsake the road of science, and get into the regions of fancy and romance.

Nickel is of a greyish white colour, and when less pure inclines a little to red.

It is both ductile and malleable. Its hardness is 8*. Its specific gravity 9,000 †. It requires for fusion a temperature at least equal to 150° Wedgewood ‡.

It is powerfully attracted by the magnet, and is even possessed of the property of attracting iron. This induced Bergman to suppose that nickel, when purest, was still contaminated with about one-third of iron: but as this is the only proof of its containing iron, Klaproth, with reason, deems it an insufficient one, and considers attraction by the magnet as a property of nickel §.

When exposed to a strong heat, nickel is oxidated slowly. Its oxide is of a brown colour; if impure, it is greenish. The oxide of nickel, according to Klaproth, is composed of 77 parts of nickel and 23 of oxygen ¶. Its affinities, according to Bergman, are as follows:

Oxalic acid,
Muriatic,
Sulphuric,
Tartarous,
Nitric,
Sebacic,
Phosphoric,
Fluoric,
Saccholactic,
Succinic,
Citric,
Formic,
Lactic,
Acetous,
Arsenic,
Boracic,
Prussic,
Carbonic,
Ammonia,
Potash?
Soda?

Cronstedt found that nickel combined readily with sulphur by fusion. The sulphuret which he obtained was yellow and hard, with small sparkling facets; but the nickel which he employed was impure.

Nickel combines very readily with phosphorus, either by fusing it along with phosphoric glass, or by dropping phosphorus into it while red hot. The phosphuret of nickel is of a white colour, and when broke exhibits the appearance of very slender prisms collected together. When heated, the phosphorus burns, and the metal is oxidated. It is composed of 83 parts of nickel and 17 of phosphorus*. The nickel, however, on which this experiment was made, was not pure.

Little is known concerning the alloys of nickel with other metals. Equal parts of silver and nickel form a white ductile alloy. Equal parts of copper and nickel form a red ductile alloy. The compounds which this metal forms with tin and zinc are brittle. It does not combine with mercury †. It has a very strong affinity for iron, cobalt, and arsenic, and is scarcely ever found except combined with some of them.

Its affinities, according to Bergman, are as follows:

Iron,
Cobalt,
Arsenic,

Copper,

Nickel.

166

Its properties,

* Kirwan's

Miner. ii.

281.

† Bergman,

ii. 231.

‡ Ibid.

§ Ann. de

Chim. i.

170.

167

Oxides,

¶ Kirwan's

Miner. ii.

490.

168

Sulphuret,

169

Phosphu-

ret,

* Pelletier,

Ann. de

Chim. xiii.

135.

170

Alloys,

† Bergman,

ii. 231.

171

And affinities.

Copper,
Gold,
Tin,
Antimony,
Platinum,
Bismuth,
Lead,
Silver,
Zinc,
Sulphuret of alkali,
Sulphur,
Phosphorus?

SECT. XV. Of Manganese.

[171]
Discovery
of manga-
nese.

THE dark grey mineral called *manganese*, in Latin *magnesia* (according to Boyle, from its resemblance to the *magnet*), has been long known and used in making glass. A mine of it was discovered in England by Mr Boyle. It was long supposed to be an ore of iron; but Port and Cronstedt having demonstrated that it contained very little of that metal, the latter referred it in his Mineralogy to a distinct order of earths, which he called *terra magnesica*. Bergman, from its specific gravity, and several other qualities, suspected that it was a metallic oxide: he accordingly made several attempts to reduce it, but without success; the whole mass either assuming the form of scoriae, or yielding only small separate globules attracted by the magnet. This difficulty of fusion led him to suspect that the metal he was in quest of bore a strong analogy to platinum. In the mean time, Dr Gahn, who was making experiments on the same mineral, actually succeeded in reducing it by the following process: He lined a crucible with charcoal powder moistened with water, put into it some of the mineral formed into a ball by means of oil, then filled up the crucible with charcoal powder, luted another crucible over it, and exposed the whole for about an hour to a very intense heat. At the bottom of the crucible was found a metallic button, or rather a number of small metallic globules, equal in weight to one-third of the mineral employed*. It is easy to see by what means this reduction was accomplished. The charcoal attracted the oxygen from the oxide, and the metal remained behind. This metal is called *manganese*.

* Bergman,
ii. 211.

172
Its proper-
ties,
† Kirwan's
Miner. ii.
288.
‡ Hielm.

Manganese is of a greyish white colour. It is not malleable, and yet not so brittle as to be easily broken.

Its hardness is 8 †. Its specific gravity is 7,000 ‡. Its fusion requires so great a heat, that it has been very seldom accomplished.

When reduced to powder, it is attracted by the magnet.

When exposed to the air, it very soon tarnishes, and assumes a darker colour, till at last it becomes black and friable. This change is produced by the absorption of oxygen. It takes place much more rapidly if heat be applied to the metal. The substance thus obtained is the *black oxide of manganese*. This oxide is found in great abundance in nature, though scarcely ever in a state of purity. It is composed of 75 parts of manganese and 25 of oxygen §.

§ Bergman,
ii. 225.

If a quantity of muriatic acid be poured upon this *Manganese* oxide, and heat applied, part of the acid combines with some of the oxygen of the oxide, and flies off in yellow fumes. The oxide is dissolved in the rest. If potash be added to this solution, a white powder is precipitated. This is the *white oxide of manganese*. It contains, according to Bergman, about 80 parts of manganese and 20 of oxygen. It soon attracts more oxygen when exposed to the air, and is converted into *black oxide*.

The affinities of the white oxide, according to Bergman, are as follows:

Oxalic acid,
Citric,
Phosphoric,
Tartarous,
Fluoric,
Muriatic,
Sulphuric,
Nitric,
Saccholaetic,
Succinic,
Sebacic,
Tartaric,
Formic,
Lactic,
Acetous,
Prussic,
Carbonic.

The sulphuret of manganese is unknown.

Phosphorus may be combined with manganese by phosphorus melting together equal parts of the metal and of phosphoric glass; or by dropping phosphorus upon red hot manganese. The phosphuret of manganese is of a white colour, brittle, granulated, disposed to crystallize, not altered by exposure to the air, and more fusible than manganese. When heated, the phosphorus burns and the metal becomes oxidated*.

Manganese combines readily with carbon by fusion (1).

Little is known concerning the alloys of manganese. It combines readily with copper. The compound, according to Bergman, is very malleable, its colour is red, and it sometimes becomes green by age. Gmelin made a number of experiments to see whether this alloy could be formed by fusing the black oxide of manganese along with copper. He partly succeeded, and proposed to substitute this alloy instead of the alloy of copper and arsenic, which is used in the arts †. We believe, however, that upon trial the new alloy has been found not to answer.

Manganese combines readily with iron; indeed it has scarcely ever been found quite free from some mixture of that metal. It combines also very easily with arsenic and tin, not easily with zinc, and not at all with mercury ‡.

The affinities of manganese, according to Bergman, are as follows:

Copper,
Iron,
Gold,

Silver,

174

Phosphu-

ret,

137.

175

Carburet,

176

Alloys,

* Pelletier,

Ann. de

Chim. xiii.

137.

177

Ann. de

Chim. i.

303.

† Bergman,

ii. 211.

177

And affini-

ties.

(1) Bergman, III. 379.—Sometimes manganese is very speedily oxidated by exposure to the air, sometimes scarcely altered by it, as Klaproth and Pelletier have observed. Mr Kirwan supposes that the manganese which is soon altered contains carbon, and that this is the cause of the difference. See *Miner.* II. 288.

Silver,
Tin,
Sulphuret of alkali,
Phosphorus?
Carbon?

Molybdenum.

The three metals, *cobalt*, *nickel*, and *manganese*, resemble iron in several particulars: Like it, they are magnetic, very hard, and very difficult to fuse: but they differ from it in specific gravity, malleability, and in the properties of all their combinations with other substances; the oxides, for instance, of iron, cobalt, nickel, and manganese, possess very different qualities.

SECT. XVI. Of Tungsten.

178
Discovery of tungsten. THERE is a mineral found in Sweden of an opaque white colour and great weight; from which last circumstance it got the name of *tungsten*, or *ponderous stone*. Some mineralogists considered it as an ore of tin, others supposed that it contained iron. Scheele analysed it in 1781, and found that it was composed of lime and a peculiar earthy-like substance, which he called from its properties *tungstic acid*. Bergman conjectured that the basis of this acid was a metal; and this conjecture was soon after fully confirmed by the experiments of Messrs D'Elhuyart, who obtained the same substance from a mineral of a brownish black colour, called by the Germans *wolfram*, which is sometimes found in tin mines. This mineral they found to contain $\frac{6}{10}$ of tungstic acid; the rest of it consisted of manganese, iron, and tin. This acid substance they mixed with charcoal powder, and heated violently in a crucible. On opening the crucible after it had cooled, they found in it a button of metal, of a dark brown colour, which crumbled to powder between the fingers. On viewing it with a glass, they found it to consist of a congeries of metallic globules, some of which were as large as a pin-head. The metal thus obtained is called *tungsten*. The manner in which it was produced is evident; tungstic acid is composed of oxygen and tungsten: the oxygen combined with the carbon, and left the metal in a state of purity.

179
Its Properties.
* Luyart.
† Id.
‡ Id.

Tungsten is externally of a brown colour, internally of a steel grey*.

Its specific gravity is 17,600 †. It is more infusible than manganese ‡.

When heat is applied to tungsten it is converted into a yellow powder, composed of 80 parts of tungsten and 20 of oxygen §. This is the *yellow oxide of tungsten* or *tungstic acid*.

The sulphuret of tungsten is of a bluish black colour, hard, and capable of crystallizing.

Phosphorus is capable of combining with tungsten ||.

Of the alloys of tungsten we know nothing, except from the experiments of Elhuyarts, which have been transcribed into the article CHEMISTRY in the *Encyclopaedia*; to which, therefore, we beg leave to refer.

SECT. XVII. Of Molybdenum.

180
Discovery of molybdenum. THE Greek word *molybdæna*, and its Latin translation *plumbago*, seem to have been employed by the ancients to denote various oxides of lead; but by the moderns they were applied indiscriminately to all substances possessed of the following properties: Light, friable, and

soft, of a dark colour and greasy feel, and which leave a stain upon the fingers. Scheele first examined these minerals with attention. He found that two very different substances had been confounded together. To one of these, which is composed of carbon and iron, and which has been already described, he appropriated the word *plumbago*; the other he called *molybdæna*.

Molybdæna is composed of scaly particles adhering slightly to each other. Its colour is bluish, very much resembling that of lead. Scheele analysed it, and obtained sulphur and a whitish powder, which possessed the properties of an acid, and which, therefore, he called *acid of molybdæna*. Bergman first suspected that the basis of this acid was a metal. It was at the request of Bergman and Scheele that Mr Hielm began the laborious course of experiments by which he succeeded in obtaining a metal from this acid. His method was to form it into a paste with linseed oil, and then to apply a very strong heat. This process he repeated several times successively. Klapproth and Pelletier also attempted to reduce it, and with equal success. The metal is *molybdenum* (κ).

Molybdenum is externally of a whitish yellow colour, but its fracture is a whitish grey. 181
Its properties.

Hitherto it has only been procured in small grains, agglutinated together in brittle masses.

Its specific gravity is 7,500. It is almost infusible in our fires.

When exposed to a strong heat, it is gradually converted into a whitish-coloured oxide*. When nitric acid is poured upon it, molybdenum attracts oxygen, and is converted into a *white oxide*, which possesses the properties of an acid †. This is the *molybdic acid*. * Pelletier, Journ. de Phys. 1785. † Ibid.

Molybdenum combines readily with sulphur; and the compound has exactly the properties of molybdæna, the substance which Scheele decomposed ‡. Molybdæna is therefore *sulphuret of molybdenum*. The reason that Scheele obtained from it molybdic acid was, that the metal combined with oxygen during his process. ‡ Ibid.

Molybdenum is also capable of combining with phosphorus §.

Few of the alloys of this metal have been hitherto examined. § Pelletier, Ann. de Chim. xiii. 137.

It seems capable of uniting with gold. The alloy is probably of a white colour ||.

It combines readily with platinum while in the state of an oxide. The compound is fusible. Its specific gravity is 20,00 ¶.

The alloys of molybdenum with silver, iron, and copper, are metallic and friable; those with lead and tin are powders which cannot be fused*. ¶ Hielm, Ann. de Chim. iv. 17. * Pelletier, Journal de Physique, Dec. 1785. 182

SECT. XVIII. Of Uranium.

182
Discovery of uranium. THERE is a mineral found in the George Wagsfort mine at Johann-Georgenstadt in Saxony, partly in a pure or unmixed state, and partly stratified with other kinds of stones and earths. The first variety is of a blackish colour inclining to a dark iron grey, of a moderate splendor, a close texture, and when broken presents a somewhat uneven, and, in the smallest particles, a conchoidal surface. It is quite opaque, tolerably hard, and on being pounded yields a black powder. Its specific gravity is about 7,500. The second sort is distinguished

Uranium. distinguished by a finer black colour, with here and there a reddish cast; by a stronger lustre, not unlike that of pitcoal; by an inferior hardness; and by a shade of green, which tinges its black colour when it is reduced to powder*.

* Klaproth, *powder* *.
 Grell's *Journal*, Eng. Transl. i. 126.
 † *Ibid.*
 This fossil was called *pechblende*; and mineralogists, misled by the name (L), had taken it for an ore of zinc, till the celebrated Werner, convinced from its texture, hardness, and specific gravity, that it was not a *blende*, placed it among the ores of iron. Afterwards he suspected that it contained *tungsten*; and this conjecture was seemingly confirmed by the experiments of some German mineralogists, published in the *Miners Journal* †. But Klaproth, whose analyses always display the most consummate skill, joined with the most rigid accuracy, examined this mineral about the year 1789, and found that it consisted chiefly of sulphur combined with a peculiar metal, to which he gave the name of *uranium* (M).

183
 Its properties.
 † *Ibid.* 233.
 Uranium is of a dark grey colour; internally it is somewhat inclined to brown †.

Its malleability is unknown. Its hardness is about 6. It requires a stronger heat for fusion than manganese. Indeed Klaproth only obtained it in very small conglutinated metallic grains, forming altogether a porous and spongy mass.—Its specific gravity is 6,440 †.

§ *Ibid.*
 When exposed for some time to a red heat, it suffers no change. By means of nitric acid, however, it may be converted into a yellow powder. This is the *yellow oxide of uranium*. This oxide is found native mixed with the mineral above described. Its affinities have not yet been determined.

Uranium is capable of combining with sulphur. The mineral from which Mr Klaproth first obtained it is a native sulphuret of uranium.

Nothing is known concerning the alloys or affinities of uranium.

SECT. XIX. Of Titanium.

184
 Discovery of titanium.
 THERE is a mineral found in Hungary which, from its external appearance, has been called *red borl*; but Klaproth, who examined it about the year 1795, discovered that it consisted chiefly of a peculiar metal, to which he gave the name of *titanium*.

185
 Its properties.
 Titanium is of a brownish red colour, and considerable lustre. It is brittle. Its hardness is 9; its specific gravity 4,18.

When exposed to a strong heat in a clay crucible, it suffered no alteration, except that its colour became browner; but in a coal crucible it lost its lustre and broke to pieces.

It is found naturally crystallized in right-angled quadrangular prisms, longitudinally furrowed, and about half an inch in length.

No acid had any effect in oxidating it; but when mixed with five times its weight of potash, and heated in a porcelain furnace, it melted, and formed when cold

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a dense greyish mass, the surface of which was crystallized. When dissolved in boiling water, it soon let fall a white powder, weighing about one-third more than the titanium employed. This is the *oxide of titanium*. Fifty grains of it were reduced by ignition to 38. While hot it was yellowish, but, like oxide of zinc, became white as it cooled. When heated on charcoal, it assumes first a *rosy red*, and afterwards a *slate blue* colour, and at last melts into an imperfect bead with a finely striated surface. Mr Klaproth did not succeed in reducing it to the metallic state.

Titanium does not seem to have any affinity for sulphur*.

There was a substance discovered by Mr M'Gregor in the valley of Menachan in Cornwall, and hence called *menachanite*. Upon this substance Mr M'Gregor made a very interesting set of experiments, which were published in the *Journal de Physique* for 1791. He suspected it to contain a new metal. From its properties, Mr Kirwan conjectured that it was the same with titanium †; and this conjecture has been very lately confirmed by Mr Klaproth, who analysed *menachanite*, and found it to be an ore of that metal.

SECT. XX. Of Tellurium.

187
 Discovery of tellurium.
 IN the mountains of Fatzbay, near Zalethna in Transylvania, there is a mine called *Mariabils*; the ore of which is wrought for the gold that it contains. Mr Muller of Reichenstein examined it in 1782, and suspected that it contained a new metal; and Bergman, to whom he had sent some of the ore, was of the same opinion: but the quantity of the mineral which these chemists had examined was too inconsiderable to enable them to decide with certainty. Klaproth analysed a larger quantity of it about the year 1797, and found that 1000 parts of it consisted of 72 parts of iron, 2,5 of gold, and 925,5 of a new metal, to which he has given the name of *tellurium* (N).

Tellurium is of a white colour like tin, approaching somewhat to the grey colour of lead †.

It is very brittle and friable. Its fracture is laminated. Its specific gravity is 6,115.

It is as easily melted as lead. When suffered to cool quietly and gradually, it readily assumes a crystallized surface †.

When heated by the blowpipe upon charcoal, it burns with a very lively flame of a blue colour, inclining at the edges to green. It is so volatile as to rise entirely in a whitish grey smoke; at the same time it exhales a disagreeable odour like that of radishes. This smoke is the *white oxide* of tellurium, which may be formed also by dissolving the metal in nitro-muriatic acid, and pouring into the saturated solution a quantity of water: a white powder precipitates, which is the oxide †.

When this oxide is heated for some time in a retort, it melts, and appears, after cooling, of a yellow straw colour, having acquired a sort of radiated texture. When

I i formed

Tellurium

* M'Gregor, 186
 Menachanite.

† Mineral. ii. 331.

187
 Discovery of tellurium.

188
 Its properties.

† Klaproth, *Philosophical Magazine*, i. 78.

§ Muller.

|| Klaproth.

(L) *Blende* is the name given to ores of zinc.

(M) From *Uranus* (*Ουρανός*), the name given by Mr Bode to the new planet discovered by Herschel; which name the German astronomers have adopted. Mr Klaproth called the metal at first *uranite*; but he afterwards changed that name for *uranium*.

(N) Mr Kirwan, in the new edition of his *Mineralogy*, which was published before Mr Klaproth's experiments were known, gives this metal the name of *Sylvanite*.—Tellurium exists in several other mines in the same mountains.

Tellurium. formed into a paste with any fat oil, and distilled in a red heat, brilliant metallic drops are observed to cover the upper part of the retort, which at intervals fall to the bottom of the vessel, and are immediately replaced by others. After cooling, metallic fixed drops are found adhering to the sides and at the bottom of the vessel; the remainder of the metal is reduced. Its surface is brilliant and almost always crystallized. When this oxide is exposed to heat on charcoal, it is reduced with a rapidity that resembles detonation*.

* *Klaproth.* Tellurium combines with sulphur. The sulphuret of this metal is of a grey colour and radiated structure.

When placed on red hot charcoal, the metal burns as well as the sulphur with a blue flame.

Tellurium amalgamates with mercury by simple trituration†.—The other properties of this metal are unknown. † *Muller.*

A NEW metal has lately been discovered by Vauquelin in the red lead ore of Siberia. It is grey, very hard, brittle, and easily crystallizes in small needles ‡. He has given it the name of *chromum* (o). † *Nicholson's Journal*, ii. 146.

We have now described all the metals at present known. The following table will exhibit in one view their principal properties.

Metals.	Colour.	Hardness.	Specific gravity	Fusing Point.	Malleability.	Ductility	
Gold.	Yellow.	6	19,300	32 W. (P) 1298 F.	282000	500	
Silver.	White.	6½	10,510	28 W. 1044 F.	160000	270	
Platinum.	White.	7½	23,000	150 W.?		above 500	
Mercury.	White.		13,568	—39 F.			
Copper.	Red.	8	8,870	27 W. 1449 F.		299½	
Iron.	Blue-grey.	9	7,788	150 W. 20577 F.		450	Magnetic.
Tin.	White.	6	7,299	410 F.	2000	49	
Lead.	Blue-white.	5	11,352	540 F.		29½	
Zinc.	White.	6	7,190	700 F.		0	
Antimony.	Grey.	6½	6,860	700 F.	0	0	
Bismuth.	Yellow-white.	6	9,822	460 F.	0	0	
Arsenic.	White.	7	8,310	400 F.?	0	0	
Cobalt.	White.	8	8,150	130 W. 17977 F.			Magnetic.
Nickel.	White.	8	9,000	150 W. 20577 F.			Magnetic.
Manganese.	White.	8	7,000	150 W. 20577 F.	0	0	Magnetic.
Tungsten.	Brown.	6	17,600		0	0	
Molybdenum	Grey.		7,500		0	0	
Uranium.	Grey.	6	6,440				
Titanium.	Red.	9	4,180		0	0	
Tellurium.	White.		6,115	540 F.	0	0	
Chromum.	Grey.				0	0	

190
General table of the properties of the metals.

(o) From *χρῶμα*, because it possesses the property of giving colour to other bodies in a remarkable degree.
(P) W. Wedgwood's pyrometer. F. Fahrenheit's thermometer. We

Part I.

Tellurium.
191
Remarks
on metallic
oxides.

We have seen that all the metals are capable of combining with oxygen; that almost every one forms various oxides, containing different quantities of oxygen, and varying in colour and other properties according to the proportion of oxygen which they contain. No part of chemistry has more engaged the attention of philosophers than the metallic oxides; and yet such is the difficulty of the subject, that scarcely any part of chemistry is more imperfectly understood.

We neither know how many oxides every particular metal is capable of forming, nor the manner in which they are formed: neither have the differences between oxides of the same metallic base been inquired into; though there cannot be a doubt that they differ, not only in their affinities, but in many of their other properties. The *white oxide* of manganese, for instance, combines readily with acids, but the *black* is incapable of uniting with any.

Mr Proust, in a very valuable paper which he lately published concerning the oxides of iron*, hints that metals are only capable of two degrees of oxidation, or, which is the same thing, that only two different oxides can be produced from the same metal. We think he has proved this completely as far as iron is concerned; and probably the observation holds good with respect to many other metals. Arsenic, copper, tin, molybdenum, and perhaps even mercury, seem to be capable of only two degrees of oxidation; but it would require a very numerous and accurate set of experiments to be able to determine the matter, or even to form a probable conjecture. Analogy is certainly against the supposition; for it has been demonstrated that some substances at least are capable of combining with three different doses of oxygen (Q), and why may not this be the case also with the metals?

There is one observation, however, which we owe to Mr Proust, the truth of which cannot be doubted, and which is certainly of the highest importance—that metals are not capable of indefinite degrees of oxidation, but only of a certain number; and that every particular oxide consists of a determinate quantity of the metal and of oxygen chemically combined. Iron, for instance, is not capable, as has been supposed, of uniting with oxygen in all the intermediate degrees between $\frac{7}{100}$ and $\frac{8}{100}$, and consequently of forming 20 or 30 different oxides; it can only combine with precisely $\frac{7}{100}$ parts, or $\frac{8}{100}$ parts, and with no other proportions; and therefore is only capable of forming two oxides, the *green* and the *brown*. In like manner, every other metal combines with certain proportions of oxygen, and forms either two oxides or more according to its nature. To talk therefore of oxidating a metal indefinitely is not accurate, except it be intended to signify the combining of part of it with oxygen, while the rest remains in its natural state. If iron be oxidated at all, it must be combined with $\frac{7}{100}$ of oxygen; if it be oxidated more than this, it must be combined with $\frac{8}{100}$ of oxygen.

We beg leave to add another observation, which we consider as of no less importance, and which will serve in some measure to modify and explain what has been just now said. Oxygen is capable of uniting with me-

tals, or with any other substance for which it has an affinity, only in *one* determinate proportion. Iron, for instance, and oxygen can only combine in the proportion of 73 parts of iron and 27 of oxygen. These two quantities saturate each other, and form a compound which is incapable of receiving into it any more oxygen or iron: this compound is the *green oxide of iron*. How comes it then, it will be asked, that there is another oxide of iron, the *brown oxide*, which contains 52 parts of iron and 48 of oxygen, proportions certainly very different from 73 and 27? We answer, there is an affinity between the green oxide of iron and oxygen; they are capable of combining together, and of saturating each other in the proportion of about 71,5 parts of green oxide and 28,5 of oxygen; and the compound which they form is the *brown oxide*, which of course contains 52 parts of iron and 48 of oxygen: But then it is not formed by the combination of these two substances directly, but by the combination of the green oxide and oxygen. In like manner, the arsenic acid is not composed of arsenic and oxygen combined directly, but of white oxide of arsenic combined with oxygen. The very same thing takes place in all the other metals. We cannot at present prove the truth of this observation in a satisfactory manner, because it would be necessary to draw our proofs from combinations which are yet undescribed; but we will have occasion to consider it afterwards.

We have seen that all the metals hitherto tried are capable of combining with sulphur, except gold and titanium; that all of them on which the experiments have been made can be united with phosphorus; and that three of them, iron, zinc, and manganese, united with carbon; and perhaps many more of them may hereafter be found capable of assuming the form of carburets.

We have seen, too, that they are capable of uniting with one another and forming alloys. This was long reckoned peculiar to metals, and it is at present one of the best criterions for determining the metallic nature of any substance. Much is wanting to render the chemistry of alloys complete. Many of them have never been examined; and the proportions of almost all of them are unknown. Neither has any accurate method been yet discovered of determining the affinities of metals for each other. The order of affinities which we have given for each metal was determined by Bergman; but he acknowledged himself that he wanted the proper data to ensure accuracy.

CHAP. IV. OF EARTHS.

THE word *earth*, in common language, has two meanings; it sometimes signifies the *globe* which we inhabit, and sometimes the *mould* on which vegetables grow. Chemists have examined this mould, and have found that it consists of a variety of substances mixed together without order or regularity. The greatest part of it, however, as well as of the stones, which form apparently so large a proportion of the globe, consists of a small number of bodies, which have a variety of common properties.

I i 2

(Q) We shall see afterwards that azot is one of these.

Lime. perties. These bodies chemists have agreed to class together, and to denominate *earths*.

192
Properties of earths.

Every body which possesses the following properties is an *earth*:

1. Insoluble in water, or nearly so; or at least becoming insoluble when combined with carbonic acid.
2. Little or no taste or smell; at least when combined with carbonic acid.
3. Incombustible, and incapable while pure of being altered by the fire.
4. A specific gravity not exceeding 4,9.
5. When pure, capable of assuming the form of a white powder.

The earths at present known amount to ten; the names of which are, lime, magnesia, barytes, strontites, alumina, silica, jargonite, glucina, yttria, agustina.

Every one of the above characteristics is not perhaps rigorously applicable to each of these bodies; but all of them possess a sufficient number of common properties to render it useful to arrange them under one class.

SECT. I. Of Lime.

LIME has been known from the earliest ages. The ancients employed it in medicine; it was the chief ingredient in their mortar; and they used it as a manure to fertilize their fields.

193
Method of procuring lime.

It abounds in many parts of the world, or perhaps we should rather say, that there is no part of the world where it does not exist. It is found purest in limestones, and marbles and chalk. None of these substances, however, is, strictly speaking, lime; but they are all capable of becoming lime by a well-known process, by keeping them for some time in a white heat: this process is called *the burning of lime*; the product is denominated *quicklime*. This last substance is what we call *lime*.

194
Properties of lime.

Pure lime is of a white colour, moderately hard, but easily reduced to a powder.

It has a hot burning taste, and in some measure corrodes and destroys the texture of those animal bodies to which it is applied. It has no smell. Its specific gra-

* Kirwan's vity is 2,3*.

Miner. i. 5.

If water be poured on newly burnt lime, it swells and falls to pieces, and is soon reduced to a very fine powder. In the mean time, so much heat is produced, that part of the water flies in vapour. If the quantity of lime slacked (as this process is termed) be great, the heat produced is sufficient to set fire to combustibles. In this manner vessels loaded with lime have sometimes been burnt. When great quantities of lime are slacked in a dark place, not only heat, but light also is emitted, as Mr Pelletier has observed †. When slacked lime is weighed, it is found to be heavier than it was before. This additional weight is owing to the combination of part of the water with the lime; which water may be separated again by the application of a red heat; and by this process the lime becomes just what it was before being slacked ‡.

† Journ. de Phys. t. 22

‡ Dr Black.

195
Lime-water.

§ Kirwan's Miner. i. 5.

Six hundred parts of water, at the temperature of 60°, dissolve about one part of lime; boiling hot water dissolves about double that quantity §. This solution is called *lime-water*. It is limpid, has an acrid taste, and changes vegetable blue colours to green. One ounce troy of lime-water contains about one grain of lime.

One thousand parts of lime are capable of absorbing, and retaining, at a heat of 600°, 228 parts of water*.

Lime.
* Lavoisier.

Lime has never yet been obtained in the state of crystals.

It is incapable of being fused by the most violent heat that can be produced in furnaces, or even by the most powerful burning-glasses.

Lime unites readily with sulphur, and forms *fulphuret of lime*. This compound may be obtained by mixing unslacked lime and flowers of sulphur together, and adding a little water. The heat produced by the slacking of the lime is sufficient to make the sulphur and the lime unite. This fulphuret is of a red colour. When water is poured on it, sulphurated hydrogen gas is emitted. The sulphur is gradually converted into sulphuric acid by uniting with the oxygen of the water, the hydrogen of which flies off in the form of gas, dissolving at the same time a part of the sulphur.

It is capable also of combining with phosphorus.—The phosphuret of lime decomposes water by the assistance of a moderate heat, and gives out phosphurated hydrogen gas.

Limestone and chalk, though they are capable of being converted into lime by *burning*, possess hardly any of the properties of that active substance. They are tasteless, scarcely soluble in water, and do not perceptibly act on animal bodies. Now, to what are the new properties of lime owing? What alteration does it undergo in the fire?

It had been long known that limestone loses a good deal of weight by being burned or *calcined*. It was natural to suppose, therefore, that something was separated from it during calcination. Accordingly, Van Helmont, Ludovicus, and Macquer, made experiments in succession, in order to discover what that *something* was; and they concluded from them that it was *pure water*, which the lime recovered again when exposed to the atmosphere. As the new properties of lime could hardly be ascribed to this loss, but to some other cause, Stahl's opinion, like all the other chemical theories of that wonderful man, was generally acceded to. He supposed that the new properties which lime acquired by calcination, were owing entirely to the more minute division of its particles by the action of the fire. Boyle indeed had endeavoured to prove, that these properties were owing to the *fixation of fire* in the lime: a theory which was embraced by Newton and illustrated by Hales, and which Meyer new modelled, and explained with so much ingenuity and acuteness as to draw the attention of the most distinguished chemists. But while Meyer was thus employed in Germany, Dr Black, of Edinburgh, published those celebrated experiments which form so brilliant an era in the history of chemistry.

He first ascertained that the quantity of water separated from limestone during its calcination was not nearly equal to the weight which it lost. He concluded in consequence that it must have lost something else than mere water. What this could be, he was at first at a loss to conceive; but recollecting that Dr Hales had proved, that limestone, during its solution in acids, emitted a great quantity of *air*, he conjectured that *this* might probably be what it lost during calcination. He calcined it accordingly, and applied a pneumatic apparatus to receive the product. He found his conjecture verified;

196
Sulphuret, and
197
Phosphuret of lime.
198
Cause of the difference between limestone and lime.

199
According to Stahl;

200
Explained by Dr Black.

Part I.

Lime.

verified; and that the *air* and the *water* which separated from the lime, were together precisely equal to the loss of weight which it had sustained. Lime therefore owes its new properties to the loss of *air*; and limestone differs from lime merely in being combined with a certain quantity of *air*: for he found that, by restoring again the same quantity of *air* to lime, it was converted into limestone. This *air*, because it existed in lime in a fixed state, he called *fixed air*. It was afterwards examined by Dr Priestley and other philosophers, found to possess peculiar properties, and to be that species of gas now known by the name of *carbonic acid gas*. Lime then is a simple substance, that is to say, it has never yet been decomposed; and limestone is composed of carbonic acid and lime. Heat separates the carbonic acid, and leaves the lime in a state of purity.

The affinities of lime, according to Bergman, are as follows:

Oxalic acid,
Suberic (R)?
Sulphuric,
Tartarous,
Succinic,
Phosphoric,
Saccholaric,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Arsenic,
Formic,
Lactic,
Citric,
Benzoic,
Sulphurous,
Acetous,
Boracic,
Nitrous,
Carbonic,
Prussic,
Sulphur,
Phosphorus,
Water,
Fixed oil.

SECT. II. Of Magnesia.

ABOUT the beginning of the eighteenth century, a Roman canon exposed a white powder to sale at Rome as a cure for all diseases. This powder he called *magnesia alba*. He kept the manner of preparing it a profound secret; but in 1707 Valentini informed the public that it might be obtained by calcining the lixivium which remains after the preparation of nitre; and two

years after, Slevogt discovered that it might be precipitated by potash from the mother ley (s) of common salt. This powder was generally supposed to be *lime*, till Frederic Hoffman observed that it formed very different combinations with other bodies*. But little was known concerning its nature till Dr Black published his celebrated experiments in 1755. Margraf published a dissertation on it in 1759, and Bergman another in 1775, in which he collected the observations of these two philosophers, and which he enriched also with many additions of his own.

As magnesia has never yet been found native in a state of purity, it may be prepared in the following manner: *Sulphat of magnesia*, a salt composed of this earth and sulphuric acid, exists in sea-water, and in many springs, particularly some about Epsom, from which circumstance it was formerly called *Epsom salt*. This salt is to be dissolved in water, and half its weight of potash added. The magnesia is immediately precipitated, because potash has a stronger affinity for sulphuric acid. It is then to be washed with a sufficient quantity of water, and dried.

Magnesia thus obtained is a very soft white powder, which has very little taste, and is totally destitute of smell. Its specific gravity is about 2,3†.

It is soluble in about 7900 times its own weight of water at the temperature of 60°‡.

Even when combined with carbonic acid (for which it has a strong affinity) it is capable of absorbing and retaining 1½ times its own weight of water, without letting go a drop; but on exposure to the air, this water evaporates, though more slowly than it would from lime.

Magnesia has never yet been obtained in a crystallized form.

It tinges vegetable blues of an exceedingly slight green.

It is not melted by the strongest heat which it has been possible to apply; but Mr D'Arcet observed that, in a very high temperature, it became somewhat agglutinated.

When magnesia and sulphur are put into a vessel of water, and kept for some time exposed to a moderate heat, they combine, and form sulphuret of magnesia; which, according to Fourcroy, is capable of crystallizing.

The phosphuret of magnesia has never been examined.

Equal parts of lime and magnesia mixed together, and exposed by Lavoisier to a very violent heat, did not melt; neither did they melt when Mr Kirwan placed them in the temperature of 150° Wedgwood. The following Table, drawn up by Mr Kirwan from his own experiments, shews the effect of heat on these two earths mixed together in different proportions.

Proportions.

(R) The affinity of this acid for lime is inferior to the oxalic, which decomposes the suberat of lime. *Jameson's Mineral, of Shetland and Arran*, p. 168.

(s) *The mother ley* is the liquid that remains after as much as possible of any salt has been obtained from it. Common salt, for instance, is obtained by evaporating sea-water. After as much salt has been extracted from a quantity of sea-water as will crystallize, there is still a portion of liquid remaining. This portion is the *mother ley*.

201
Affinities
of lime.

203

Method of
procuring

204

Its proper-
ties.

† Kirwan's

Miner. i. 8.

‡ Ibid.

202
Discovery
of magne-
sia.Effect of
heat on
mixtures
of lime and
magnesia.

Magnesia.	Proportions.	Heat.	Effect.
	80 Lime 20 Mag.	150° Wedg.	Went through the crucible.
	75 Lime 25 Mag.	160	Went through the crucible.
	66 Lime 33 Mag.		Went through the crucible.
	20 Lime 80 Mag.	165	Did not melt.
	33 Lime 66 Mag.	138	Did not melt.
	30 Lime 10 Mag.	156	Melted into a fine greenish yellow glass; but the crucible was corroded throughout.

²⁰⁶ Affinities of Magnesia. The affinities of magnesia, according to Bergman, are as follows:

Oxalic acid,
Phosphoric,
Sulphuric,
Fluoric,
Sebacic,
Arsenic,
Saccholaric,
Succinic,
Nitric,
Muriatic,
Tartarous,
Citric,
Formic,
Lactic,
Benzoic,
Acetous,
Boracic,
Sulphurous,
Nitrous,
Carbonic,
Prussic,
Sulphur,
Phosphorus?
Water.

SECT. III. Of Barytes.

²⁰⁷ Discovery of barytes.

A VERY heavy mineral is found in Sweden, Germany, and Britain, which Margraf considered as a compound of sulphuric acid and lime. But Scheele and Gahn analysed it in 1774, and found that it consisted of sulphuric acid combined with a peculiar species of earth. This analysis was soon after confirmed and extended by Bergman. The earth was at first called *terra ponderosa*, *heavy earth*, on account of the great specific gravity of the substance from which it was obtained. Morveau called it *barote* (from *βαρος*, *heavy*), which Bergman changed into *barytes*; and this last term is now universally adopted.

Barytes is generally found combined either with sulphuric or carbonic acid. From the first of these compounds, which is by far the most common, it may be obtained by the following process:

Barytes.
²⁰⁸ Method of obtaining

Reduce the mineral to a powder and mix it with $2\frac{1}{2}$ it. its weight of carbonat of soda (τ), previously deprived of all its water. Expose the mixture to a red heat for an hour and a half, avoiding fusion, and a double decomposition takes place; the sulphuric acid unites with the soda, while the carbonic acid combines with the barytes. Wash it in a sufficient quantity of water to dissolve the compound of sulphuric acid and soda, the carbonat of barytes, which is almost insoluble, remains behind. Lest it should be mixed with some other earths, which is generally the case, boil it for three hours in ten times its weight of distilled vinegar, the specific gravity of which is 1.033; by which the barytes will be dissolved, and likewise the lime and magnesia, if there happen to be any; but every other earth (υ) remains untouched. Pour off the solution, and add to it sulphuric acid as long as any precipitate is formed. This precipitate consists of the whole barytes and the lime (if there be any) combined with sulphuric acid. Wash it in 50 times its weight of water, and all the lime will be dissolved. There will now remain nothing but barytes combined with sulphuric acid, which may be decomposed as before by carbonat of soda*. The carbonic acid may then be separated by applying a very violent heat †; or, what is better, nitric acid may be poured upon it, which will separate the carbonic acid and combine with the barytes; and then the nitric acid may be driven off by a moderate heat ‡.

Barytes thus obtained is a light, spongy, porous body, which may be very easily reduced to powder. It has a harsh and more caustic taste than lime; and when taken into the stomach, proves a most violent poison. It has no perceptible smell.

Its specific gravity has not yet been ascertained.

It imbibes water with a hissing noise, but, according to Dr Hope, without swelling or splitting as lime does §. However, when exposed to the air, as Fourcroy and Vauquelin inform us, it effloresces, cracks, bursts, swells up, heats, and becomes white, by absorbing moisture ||.

Cold water dissolves about $\frac{1}{3}$ th part of its weight of barytes, and boiling water more than half its weight. As the water cools, the barytes is deposited in crystals, the shape of which varies according to the rapidity with which they have been formed. When most regular, they are flat hexagonal prisms, having two broad sides, with two intervening narrow ones, and terminated at each end by a four-sided pyramid, which in some instances constitutes the larger part of the crystal. When formed slowly, they are distinct and large; but when the water is saturated with barytes, they are deposited rapidly, and are generally more slender and delicate. Then, too, they are attached to one another in such a manner as to assume a beautiful foliaceous appearance, not unlike the leaf of a fern ¶.

These crystals are transparent and colourless, and appear to be composed of about 53 parts of water and 47

(τ) Soda is an alkali, which shall be afterwards described. Carbonat of soda is soda combined with carbonic acid, the common state in which it is obtained; potash might also be used.

(υ) Except frontites, which Pelletier has detected in this mineral.

¶ Hope, *ibid.*

Barytes. of barytes. When exposed to the heat of boiling water, they undergo the watery fusion, or, which is the same thing, they melt without losing any of the water which they contain. A stronger heat makes the water fly off. When exposed to the air, they attract carbonic acid, and crumble into dust. They are soluble in $17\frac{1}{2}$ parts of water at the temperature of 60° ; but boiling water dissolves any quantity whatever: the reason of which is evident; at that temperature their own water of crystallization is sufficient to keep them in solution *.

* *Id.* Water saturated with barytes is called *barytic water*. It has the property of converting vegetable blues to a green.

When barytes is exposed to the blowpipe on a piece of charcoal, it fuses, bubbles up, and runs into globules, which quickly penetrate the charcoal †. This is probably in consequence of containing water; for Lavoisier found barytes not affected by the strongest heat which he could produce.

† *Fourcroy and Vauquelin, ibid.*

²¹⁰ Sulphuret of barytes. Barytes combines readily with sulphur. The easiest way of forming sulphuret of barytes is to mix eight parts of sulphat of barytes with one part of pounded charcoal, and to apply a strong heat. The charcoal combines with the oxygen of the sulphuric acid, and the compound flies off in the form of carbonic acid gas. There remains behind sulphur combined with barytes. Sulphuret of barytes is soluble in water: It is of a yellow colour. It is capable of crystallizing; and then assumes a yellowish white colour ‡.

‡ *Fourcroy.* The phosphuret of barytes has not been examined.

No mixture of barytes and lime, nor of barytes and magnesia, is fusible in the strongest heat which it has been possible to apply §.

§ *Lavoisier, Acad. Par. 1782.* The affinities of barytes, according to Bergman, are as follows:

²¹¹ Its affinities.

- Sulphuric acid,
- Oxalic,
- Succinic,
- Fluoric,
- Phosphoric,
- Saccholaric,
- Suberic (v) †
- Nitric,
- Muriatic,
- Sebacic,
- Citric,
- Tartarous,
- Arsenic,
- Fluoric,
- Lactic,
- Benzoic,
- Acetous,
- Boracic,
- Sulphurous,
- Nitrous,
- Carbonic,
- Prussic,
- Sulphur,
- Phosphorus,
- Water,
- Fixed oils.

SECT. IV. Of Strontites.

ABOUT the year 1787, a mineral was brought to Edinburgh, by a dealer in fossils, from the lead mine of Strontian in Argyleshire, where it is found imbedded in the ore, mixed with several other substances. It is sometimes transparent and colourless, but generally has a tinge of yellow or green. Its hardness is 5. Its specific gravity varies from 3,4 to 3,726. Its texture is generally fibrous; and sometimes it is found crystallized in slender prismatic columns of various lengths *.

* *Hope, E-din. Transf. iv. 44.*

This mineral was generally considered as a carbonate of barytes; but Dr Crawford having observed some differences between its solution in muriatic acid and that of barytes, mentioned in his treatise on *Muriat of Barytes*, published in 1790, that it probably contains a new earth, and sent a specimen to Mr Kirwan that he might examine its properties. Dr Hope had also suspected that its basis differed from barytes; and accordingly he made a set of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1792. These experiments fully proved that it contained a peculiar earth. Mr Kirwan likewise analysed the strontian mineral, and drew precisely the same conclusions. It has been analysed also by Mr Klaproth of Berlin, and Mr Pelletier of Paris. It consists of carbonic acid combined with a peculiar earth, to which Dr Hope gave the name of *strontites*. This appellation we shall adopt.

The carbonic acid may be separated by a heat of 140° Wedgewood, and then the strontites remains behind †.

Strontites has been found in Argyleshire in Scotland, near Bristol in England, and in Pennsylvania ‡. It has been found also in France and in Sicily. It is of a white colour. It has a pungent acrid taste. When pounded in a mortar, the powder that rises is offensive to the nostrils and lungs §. It is not poisonous ||.

† *Kirwan's Miner. i. 332.*
‡ *Klaproth, ij. sect. 39.*
§ *Hope, ibid.*
|| *Pelletier.*

One hundred and sixty-two parts of water, at the temperature of 60° , dissolve nearly one part of it. The solution is clear and transparent, and converts vegetable blues to a green. Hot water dissolves it in much larger quantities; and as it cools the strontites is deposited in colourless transparent crystals. These are in the form of thin quadrangular plates, generally parallelograms, the largest of which seldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener consist of two facets, meeting together and forming an angle like the roof of a house. These crystals generally adhere to each other in such a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they assume a cubic form. They contain about 68 parts in 100 of water. They are soluble in 51,4 parts of water, at the temperature of 60° . Boiling water dissolves nearly half its weight of them. When exposed to the air, they lose their water, attract carbonic acid, and fall into powder ¶.

¶ *Hope, ibid.*

When strontites is thrown into water, it attracts it with a hissing noise, much heat is produced, and it falls into powder much more rapidly than lime *.

It combines with sulphur either by fusion in a crucible, or by being boiled with it in water. The sulphuret.

(v) Suberic acid decomposes muriat and nitrat of barytes. *Jameson's Mineral. of Shetland and Arran.*

Silica. phuret is of a dark yellowish brown colour. It is soluble in water*.

* *Id.* 214
Its affinities. The affinities of stontites, as ascertained by Dr Hope, are as follows :

- Sulphuric acid,
- Oxalic,
- Tartarous,
- Fluoric,
- Nitric,
- Muriatic,
- Succinic,
- Phosphoric,
- Acetous,
- Arsenic,
- Boracic,
- Carbonic.

SECT. V. *Of Silica.*

²¹⁵ Method of obtaining silica. If one part of powdered flints or sand, mixed with three parts of potash, be put into a crucible, and kept in a state of fusion for half an hour, a brittle mass will be formed almost as transparent as glass, which quickly attracts moisture from the atmosphere, and is entirely soluble in water. This solution is called *liquor silicum*, or *liquor of flints*. It was first accurately described by Glauber, a chemist who lived about the middle of the 17th century.

If an acid be poured into this liquor, a white spongy substance is precipitated, which may be purified from every accidental mixture by washing it in acids, muriatic acid for instance. This substance is called *siliceous earth* or *silica*. It was first distinguished as a peculiar earth by Pott in 1746, though it had been known long before; and Cartheuser, Scheele, and Bergman, proved in succession that it could not, as some chemists had supposed, be reduced to any other earth.

²¹⁶ Its properties. Silica, when dried, is a soft white powder, without either taste or smell.

† *Kirwan's Min.* i. 10. Its specific gravity is 2,66 †. It is insoluble in water except when newly precipitated from the liquor silicum, and then one part of it is soluble in 1000 parts of water †. It has no effect on vegetable colours.

‡ *Ibid.* It is capable of absorbing about one-fourth of its weight of water, without letting any drop from it; but on exposure to the air, the water evaporates very readily §.

§ *Ibid.* Silica may be formed into a paste with a small quantity of water: this paste has not the smallest ductility, and when dried forms a loose, friable, and incoherent mass ||.

¶ *Scheele.* Silica is capable of assuming a crystalline form. Crystals of it are found in many parts of the world. They are known by the name of *rock crystal*. When pure they are transparent and colourless like glass: they assume various forms; the most usual is a hexagonal prism, surmounted with hexagonal pyramids on one or both ends, the angles of the prism corresponding with those of the pyramids. Their hardness is very great, amounting to eleven. Their specific gravity is 2,653 ¶¶.

¶ *Kirwan's Min.* i. 242.

There are two methods of imitating these crystals by art. The first method was discovered by Bergman. He dissolved silica in fluoric acid, the only acid in which it is soluble, and allowed the solution to remain undisturbed for two years. A number of crystals were then found at the bottom of the vessel, mostly of irregular figures, but some of them cubes with their angles truncated. They were hard, but not to be compared in this respect with rock crystal*.

Silica.

* *Bergman, Pro. ii. 32.*

The other method was discovered by accident. Professor Seigling of Erfurt had prepared a liquor silicum, which was more than usually diluted with water, and contained a superabundance of alkali. It lay undisturbed for eight years in a glass vessel, the mouth of which was only covered with paper. Happening to look to it by accident, he observed it to contain a number of crystals; on which he sent it to Mr Trommsdorff, professor of chemistry at Erfurt, who examined it. The liquor remaining amounted to about two ounces. Its surface was covered by a transparent crust, so strong that the vessel might be inverted without spilling any of the liquid. At the bottom of the vessel were a number of crystals, which proved on examination to be sulphat of potash and carbonat of potash (w). The crust on the top consisted partly of carbonat of potash, partly of crystallized silica. These last crystals had assumed the form of tetrahedral pyramids in groups; they were perfectly transparent, and so hard that they struck fire with steel †.

Silica endures the most violent heat without alteration. † *Nicholson's Jour.* i. 217.

It seems incapable of combining with sulphur or phosphorus.

1. The effect of heat upon lime and silica, mixed in various proportions, will appear from the following experiments of Mr Kirwan †.

Proportions.	Heat.	Effect.
50 Lime 50 Silica	150° Wedg.	Melted into a mass of a white colour, semitransparent at the edges, and striking fire, though feebly, with steel: it was somewhat between porcelain and enamel.
80 Lime 20 Silica	156	A yellowish white loose powder.
20 Lime 80 Silica	156	Not melted, formed a brittle mass.

2. Equal part of magnesia and silica melt with great difficulty into a white enamel when exposed to the most violent heat which can be produced §. They are infusible in inferior heats in whatever proportion they are mixed ||.

3. The effect of heat on various mixtures of barytes and silica will appear from the following experiments of Mr Kirwan ¶.

proportions. † *Achard, Mem. Berl.* 1780, p. 33. ¶ *Mineral.* i. 57.

(w) Potash, combined with sulphuric acid and with carbonic acid.

Silica.	Proportions.	Heat.	Effect.
80 Silica 20 Barytes		155° Wedg.	A white brittle mafs.
75 Silica 20 Barytes		150	A brittle hard mafs, semi-transparent at the edges.
66 Silica 33 Barytes		150	Melted into a hard somewhat porous porcelain mafs.
50 Silica 50 Barytes		148	A hard mafs not melted.
20 Silica 80 Barytes		148	The edges were melted into a pale greenish matter between a porcelain and enamel.
25 Silica 75 Barytes		150	Melted into a somewhat porous porcelain mafs.
33 Silica 66 Barytes		150	Melted into a yellowish and partly greenish white porous porcelain.

With a small quantity of water it forms a very tough ductile paste, and does not readily mix with more.

Alumina.

In its usual state of dryness it is capable of absorbing 2½ times its weight of water, without suffering any to drop out. It retains this water more obstinately than any of the earths hitherto described. In a freezing cold it contracts more, and parts with more of its water than any other earth; a circumstance which is of some importance in agriculture*.

* *Ibid.*

Alumina has never yet been obtained in a crystallized form. It has no effect whatever on vegetable colours.

The most intense heat does not fuse it, but it has the singular property of diminishing in bulk in proportion to the intensity of the fire to which it is exposed. It becomes at the same time exceedingly hard: Mr Lavoisier rendered it capable of cutting glass; and Mr Boyle had long before done the same thing †.

† *Sbaro's Boyle, iii.*

Wedgwood took advantage of this property of alumina, and by means of it constructed an instrument for measuring high degrees of heat. It consists of pieces of clay of a determinate size, and an apparatus for measuring their bulk with accuracy: One of these pieces is put into the fire, and the temperature is estimated by the contraction of the piece. For a more complete description of this important instrument, we refer to the article THERMOMETER in the *Encycl.*

‡ *Nicholson's Jour. ii. 101.*

§ *Kirwan, i. 56.*

Alumina is hardly susceptible of combining with sulphur or phosphorus; but from the experiments of La Grange, it appears to have an affinity for carbon ‡.

1. The effect of heat on various mixtures of lime and alumina will appear from the following table §:

Proportions.	Heat.	Effect.
75 Lime 25 Alumina	150° Wedg.	Not melted.
66 Lime 33 Alumina	150	Remained a powder.
33 Lime 66 Alumina	(x)	Melted.
25 Lime 75 Alumina	(x)	Melted.
20 Lime 80 Alumina	(x)	Melted.

¶ *Effect of heat on mixtures of lime and alumina;*

2. Magnesia and alumina have no action whatever on each other, even when exposed to a heat of 150° Wedg. and alumina; †

‡ *Magnesia and alumina;*

3. The effect of heat on different mixtures of barytes and alumina will appear from the following experiments of Mr Kirwan ¶.

¶ *Ibid. i. 57.*

¶ *Barytes and alumina;*

¶ *Ibid.*

4. The effect of heat on mixtures of stromtites and silica is not known.

5. It follows from the experiments of Achard, that equal parts of lime, magnesia, and silica, may be melted into a greenish-coloured glass, hard enough to strike fire with steel; that when the magnesia exceeds either of the other two, the mixture will not melt; that when the silica exceeds, the mixture seldom melts, only indeed with him in the following proportions; three silica, two lime, one magnesia, which formed a porcelain; and that when the lime exceeds, the mixture is generally fusible*.

The affinities of silica are as follows:

Fluoric acid,
Fixed alkali.

SECT. VI. *Of Alumina.*

DISSOLVE alum in hot water, and add to the solution potash as long as any precipitate is formed. Decant off the fluid part, and wash the precipitate in a sufficient quantity of water, and then allow it to dry. The substance thus obtained is called *alumina*. Its properties were first ascertained with accuracy by Margraf.

Alumina thus obtained is a very white spongy powder, without any smell or taste.

Its specific gravity is 2,00 †. It is scarcely soluble in water, but may be diffused through it with great facility.

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K k

Proportions.

(x) These three experiments were made by Ehrman: The heat was produced by directing a stream of oxygen gas on burning charcoal, and is the most intense which it has been hitherto possible to produce.

220
And lime, magnesia, and silica.

* *Mem. Berl. Acad. and Jour. de Phys. xxiv.*
221
Affinities of silica.

222
Method of obtaining alumina.

223
Its properties
† *Kirwan's Miner. i. 9*

Proportions.	Heat.	Effect.
80 Alumina 20 Barytes	150° Wedg.	Scarcely hardened.
75 Alumina 25 Barytes	156	No sign of fusion, a loose powder.
66 Alumina 33 Barytes	152	As the former.
50 Alumina 50 Barytes	150	As the former.
20 Alumina 80 Barytes	148	Somewhat harder, but no sign of fusion.
25 Alumina 75 Barytes	150	Harder, but no sign of fusion.

either into a glass or a porcelain, according to the proportions. The only infusible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina.

That if the silica exceeds, the mixture is frequently fusible into an enamel or porcelain, and perhaps a glass; and that when the alumina exceeds, a porcelain may often be attained, but not a glass*.

8. As to the mixtures of magnesia, silica, and alumina, when the magnesia exceeds, no fusion takes place at 150°. When the silica exceeds, a porcelain may often be attained; and three parts silica, two magnesia, and one alumina, formed a glass. When the alumina exceeds, nothing more than a porcelain can be produced †.

9. Achard found that equal parts of lime, magnesia, silica, and alumina, melted into a glass. They fused also in various other proportions, especially when the silica predominated.

The affinities of alumina as follows:

- Sulphuric acid,
- Nitric,
- Muriatic,
- Oxalic,
- Arsenic,
- Fluoric,
- Sebacic,
- Tartarous,
- Succinic,
- Saccholarctic,
- Citric,
- Phosphoric,
- Formic,
- Lactic,
- Benzoic,
- Acetous,
- Boracic,
- Sulphurous,
- Nitrous,
- Carbonic,
- Prussic.

* *Ibid.* i. 73.

231
Magnesia, silica, and alumina;

† *Ibid.* i. 72.

232
And lime, magnesia, silica, and alumina.

233
Affinities of alumina.

4. Nothing is known concerning the effect of heat on mixtures of stonites and alumina.

5. Equal parts of alumina and silica harden in the temperature of 160° Wedgewood, but do not fuse*. Achard found them infusible in all proportions in a heat probably little inferior to 150° Wedgewood. Mixtures of these two earths in various proportions form *clays*, but these are seldom uncontaminated with some other ingredients.

6. From the experiments of Achard, it appears that no mixture of lime, magnesia, and alumina, in which the lime predominates, is vitrifiable, except they be nearly in the proportions of three lime, two magnesia, one alumina; that no mixture in which magnesia predominates will melt in a heat below 166°; that mixtures in which the alumina exceeds are generally fusible, as will appear

228
Alumina and silica;
* *Kirwan's Min.* i. 58.

229
Lime, magnesia, and alumina;

† *Ibid.* i. 72. from the following table †.

3 Alumina 2 Lime 1 Magnesia	A porcelain.
3 Alumina 1 Lime 2 Magnesia	A porcelain.
3 Alumina 1 Lime 3 Magnesia	Porous porcelain.
3 Alumina 2 Lime 3 Magnesia	Porous porcelain.
3 Alumina 2 Lime 2 Magnesia	Porcelain.

7. From the same experiments, and those of Kirwan, we learn, that in mixtures of lime, silica, and alumina, when the lime exceeds, the mixture is generally fusible

230
Lime, silica, and alumina;

SECT. VII. *Of Jargon.*

AMONG the precious stones which come from the island of Ceylon, there is one called *jargon*, which is of possessed of the following properties.

Its colour is various, grey, greenish white, yellowish, reddish brown, and violet. It is often crystallized, either in right angular quadrangular prisms surmounted with pyramids, or octahedrals consisting of double quadrangular pyramids. It has generally a good deal of lustre, at least internally. It is mostly semitransparent. Its hardness is from 10 to 16: Its specific gravity from 4.16 to 4.7 †.

It loses scarcely any of its weight in a melting heat; 333. for Klaproth found that 300 grains, after remaining in it for an hour and a half, were only one-fourth of a grain lighter than at first ‡. Neither was it attacked either by muriatic or sulphuric acid, even when assisted by heat. At last, by calcining it with a large quantity of soda, he dissolved it in muriatic acid, and found that 100 parts of it contained 31.5 of silica, five of a mixture of nickel,

254
Discovery of jargon.

† *Ibid.* i.

‡ *Jour. de Phys.* 36. 180.

Glucina.
235
Its properties.

el and iron, and 68 of an earth possessed of peculiar properties. This earth has been called *jargonina*.

Jargonina has a strong resemblance to alumina. It is of a white colour. Its specific gravity probably exceeds 4,000.

It differs from alumina in the compounds which it forms with other bodies, in being insoluble in a boiling solution of pure potash or soda, and in being infusible by heat when mixed with these substances in a state of dry-

* Kirwan's notes *.

Mineral. No more of its properties are yet known.
i. p. 14.

SECT. VIII. Of Glucina.

236
Discovery of glucina.

IN the beryl was discovered, some time ago by Vauquelin, a new earth, to which he gave the name of *glucina*. To obtain it pure, the beryl, reduced to powder, is to be fused with thrice its weight of potash. The mass is to be diluted with water, dissolved in muriatic acid, and the solution evaporated to dryness. The residuum is to be mixed with a large quantity of water, and the whole thrown on a filter. The silica, which constitutes more than half the weight of the stone, remains behind; while the glucina and the other earths, combined with muriatic acid, remain in solution. They are to be precipitated by means of carbonat of potash; the precipitate is to be washed, and then dissolved in sulphuric acid. When the solution, after potash has been added to it, has been evaporated to the proper consistency, alum crystals are gradually formed. When as many of these have been obtained as possible, carbonat of ammonia in excess is to be poured into the liquid, which is first to be filtered and then boiled for some time, when a white powder gradually appears. This powder is *glucina*.

237
Its properties.

It is a soft light powder, without either taste or smell, but has the property of adhering strongly to the tongue. It has no action on vegetable colours, is altogether infusible by heat, and neither hardens nor contracts in its dimensions. It is insoluble in water, but forms with a small quantity of that liquid a paste to a certain degree ductile. It does not combine with oxygen, nor with any of the simple combustibles; but sulphurated hydrogen dissolves it, and forms with it a hydro-sulphuret, similar in its properties to other hydro-sulphurets. Glucina is soluble in the liquid fixed alkalis; insoluble in ammonia, but soluble in carbonat of ammonia. It combines with all the acids, and forms with them sweet tasted salts; and hence its name, from γλυκος, *sweet*. Its other properties have not been examined.

SECT. IX. Of Yttria and Agustina.

238
Discovery and properties of yttria.

SOME time before 1788 was discovered, in the quarry of Ytterby in Sweden, a peculiar mineral, called from Professor Gadolin, who first analysed it, *gadolinite*. Its colour is black, and its fracture like that of glass. It is magnetic, and soft enough to be scratched by a knife, and sometimes even by the nail. In this mineral a new earth has been discovered by various chemists, who have agreed to give it the name of *yttria*. When separated from the other substances with which it is

combined, viz. the oxides of iron and manganese, a little lime, and a considerable quantity of silica, it has the appearance of a fine white powder, and has neither taste nor smell. It is not melted by the application of heat, has no action on vegetable blues, and is not soluble in water. It is likewise insoluble in pure alkalis; but it dissolves readily in carbonat of ammonia. It combines with acids, and forms with them salts, which have a sweet taste, and at the same time a certain degree of astringency.

Trommsdorf has lately discovered in the Saxon beryl a new earth, to which he has given the name of *Agustina*, because the salts which it forms have little or no taste. As Trommsdorf's experiments have not hitherto been repeated, the existence of this earth must continue doubtful till the conclusions of the discoverer be confirmed by other philosophers.

THESE are all the simple earths that have yet been discovered; and the first four of them have a great many common properties. They tinge vegetable blues green, they have a strong affinity for carbonic acid, and combine readily with all acids. They have sometimes been called *alkaline earths*.

None of the earths have been hitherto decomposed, nor has the smallest proof ever been brought that they are compounds. We must therefore, in the present state of chemistry, consider them as simple bodies. Many attempts, indeed, have been made to shew that there was but one earth in nature, and that all others were derived from it. The earth generally made choice of as the simplest was silica (γ). But none of these attempts, notwithstanding the ingenuity of several of the authors, has been attended with the smallest shadow of success.

We have mentioned formerly, that it was almost the universal opinion of chemists that metals were composed of some of the earths united to phlogiston; but of late an attempt has been made to prove that all the earths are metallic oxides, and that they can actually be reduced to the state of metals.

Baron had long ago suspected that alumina had somewhat of a metallic nature; and Bergman had been induced, by its great weight and several other appearances, to conjecture that barytes was a metallic oxide: But the first chemist who ventured to hint that all earths might be metallic oxides was Mr Lavoisier. * About the year 1790, soon after the publication of Mr Lavoisier's book, Mr Tondi and Professor Ruprecht, both of Schemnitz, announced, that they had obtained from barytes, by the application of a strong heat, a metal of the colour of iron, and attracted by the magnet, which they called *borbonium*; from magnesia another, which they called *austrium*; a third from lime, also called *austrium*; and a fourth from alumina, which they denominated *apulium*. Their method of proceeding was to apply a violent heat to the earths, which were surrounded with charcoal in a Hessian crucible, and covered with calcined bones in powder.

But their experiments were soon after repeated by Klaproth, Savorese, and Tihauski; and these accurate

K k 2

chemists

(γ) Mr Sage, however, pitched upon lime.

Caloric. chemists soon proved, that the pretended metals were all of them phosphurets of iron. The iron, by the violence of the heat, had been extracted from the crucible, and the phosphorus from the bones. The earths therefore must still continue a distinct class of bodies: and, as Klaproth has observed, their properties are so exceedingly different from those of metallic oxides, that the supposition of their being composed of the same ingredients is contrary to every fact, and to every analogy with which we are acquainted.

CHAP. V. Of CALORIC.

Nothing is more familiar to us than heat; to attempt to define it therefore would be unnecessary. When we say that a person feels heat, that a stone is hot, the expressions cause no difficulty; every one understands them perfectly: yet in each of these propositions the word heat has a distinct meaning. In the one, it signifies the sensation of heat; in the other, the cause of that sensation. This ambiguity, though of little consequence in common life, leads unavoidably in philosophical discussions to confusion and perplexity. It was to prevent this that the French chemists made choice of the word caloric to signify the cause of heat. When I put my hand on a hot stone, I experience a certain sensation, which I call the sensation of heat; the cause of this sensation is caloric.

241
Whether caloric be a substance.

Concerning the nature of caloric, there are two opinions which have divided philosophers ever since they turned their attention to the subject. Some suppose that caloric, like gravity, is merely a property of matter, and that it consists, some how or other, in a peculiar vibration of its particles; others, on the contrary, think that it is a distinct substance. Each of these opinions has been supported by the greatest philosophers; and the obscurity of the subject is such, that both sides have been able to produce exceedingly plausible and forcible arguments. The recent discoveries, however, in

this branch of chemistry, have rendered the latter opinion much more probable than the former. Indeed we do not see how it is possible to account for many of the phenomena of nature, unless caloric be considered as a substance, as we trust shall appear from the investigation into which we are about to enter. We mean, then, with the generality of modern chemists, to take it for granted that caloric is a substance, without pretending to be able to demonstrate the truth of our opinion, but merely because we consider it as infinitely more plausible than the other. If the receiver of an air-pump, while it contains a thermometer, be suddenly exhausted of air, the thermometer sinks several degrees, and then gradually rises again to its former height. Now if heat be owing to vibration, how comes it that the small quantity of matter remaining in the receiver is first insufficient, and afterwards sufficient to maintain the temperature? Is it not more probable that part of the caloric was carried off with the air, and that it gradually returned through the glass, which it is capable of pervading, though with difficulty*. When air is let into an exhausted receiver, the thermometer, as Lambert first observed, rises several degrees. Is not this owing to an additional quantity of caloric introduced by the air? The thermometer then sinks slowly. Is not this because the superabundant caloric gradually pervades the glass and flies off? Taking it for granted then that caloric is a substance, we proceed to examine its properties.

* See Picquet sur le Feu, ch. I.

1. When bodies become hot, or, which is the same thing, when caloric enters into them, they expand in every direction; and this expansion is proportional to the accumulation of caloric. The first and most obvious property of caloric then is the power of expanding bodies. It does not, however, expand all substances equally, and we are still ignorant of the law which it follows. All that can be done therefore is to collect facts till this law be discovered. A number of these may be seen in the following Table:

242
Caloric expands bodies.

TABLE of the Expansion of various Bodies at different Temperatures.

Temperature.	Water *.	Mercury.	Linseed oil †.	Alcohol *.	Temperature.	Water *.	Mercury.	Linseed oil †.	Alcohol *.
30°	—	—	—	100000	100°	100908	100711,8	—	104162
32	—	100000,0	100000	—	105	—	100762,7	—	—
35	100000	100030,0	—	100267	110	—	100813,6	—	—
40	99997	100081,0	—	100539	120	101404	100915,4	—	—
45	100005	100131,9	—	101818	130	—	101017,2	—	—
50	100023	100182,8	—	101105	140	—	101119,0	—	—
55	100053	100253,7	—	101401	150	102017	101220,8	—	—
60	100091	100304,6	—	101688	160	—	101322,6	—	—
65	100141	100355,5	—	101984	167	102753	—	—	—
70	100197	100406,4	—	102281	170	—	101424,4	—	—
75	100261	100457,3	—	102583	180	—	101526,2	—	—
80	100332	100508,2	—	102890	190	103617	101628,0	—	—
85	100411	100559,1	—	103202	200	—	101729,8	—	—
90	100694	100610,0	—	103517	212	104577	101835,0	107250	—
95	100790	100660,9	102560	103840	408	—	—	115160	—

* Blagden.
† Newton.

* Blagden.
† Newton.

TABLE of the Expansion of various Bodies at different Temperatures continued.

Temperature	Sulph. acid *.	Nitric acid *.	Glass †.	Air.	Oxygen gas ‡.	Azotic gas ‡.	Hydrogen gas ‡.	Nitrous gas ‡.	Carb. acid gas ‡.	Ammoniacal gas ‡.
32°	—	—	100000	100000	100000	100000	100000	100000	100000	100000
40	—	—	—	101790	—	—	—	—	—	—
45	—	100005	—	—	—	—	—	—	—	—
50	100149	100149	—	104140	—	—	—	—	—	—
55	100263	101074	100006	—	—	—	—	—	—	—
60	100382	101389	—	106560	—	—	—	—	—	—
65	100615	101767	—	—	—	—	—	—	—	—
70	100751	102096	—	108950	—	—	—	—	—	—
75	—	—	100014	—	—	—	—	—	—	—
77	—	—	—	—	104520	103400	108390	106520	111050	127910
80	—	—	—	111300	—	—	—	—	—	—
90	—	—	—	113590	—	—	—	—	—	—
100	—	—	100023	—	—	—	—	—	—	—
110	—	—	—	117580	—	—	—	—	—	—
122	—	—	100033	—	124830	121860	122830	117630	130660	184870
130	—	—	—	121870	—	—	—	—	—	—
150	—	—	100044	126030	—	—	—	—	—	—
167	—	—	100056	—	190180	176640	137420 ‡	144370	173850	358780
170	—	—	—	130090	—	—	—	—	—	—
190	—	—	100069	133970	—	—	—	—	—	—
212	—	—	100083	134890	547670 ‡	694120	139120 ‡	160290 ‡	200940 ‡	680090 ‡ (A)

§ Du Ver-
nois, Encyc.
Méthod. art.
Air.

* Kirwan.
† De Luc.

TABLE of the Expansion of Metals from 32° to 212° †.

Temperature.	Antimony.	Steel.	Iron.	Cast Iron.	Bismuth.	Copper.	Cast Brass.	Brass Wire.
32°	120000	120000	120000	120000	120000	120000	120000	120000
212	120130	120147	120151	120167	120167	120204	120225	120232
White heat }		123428*	121500*	122571*				

	Tin.	Lead.	Zinc.	Hammered Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin (B) 1
32°	120000	120000	120000	120000	120000	120000	120000	120000	120000
212	120298	120344	120355	120373	120323	120301	120247	120274	120218

† Smeaton,
Phil. Trans.
xlvi. 612.

* Rümmer.

From

(A) This mark ‡ implies that, owing to some inaccuracy in making the experiments, the numbers to which it is attached are not to be depended on.

(B) The metal whose expansion is here given was an alloy composed of three parts of copper and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus in the last column but two, the metal consisted of two parts of brass alloyed with one of zinc.

Caloric. From this table, it appears that the gases are more expanded by caloric than fluids, and fluids more than solids; and that the expansion of all bodies hitherto examined, mercury alone excepted, goes on in an increasing series. To the expanding power of caloric there is one singular exception: From 30° to 40° Fahrenheit, water, instead of being expanded, suffers a remarkable contraction, as is evident from the following table of its bulk for every degree between 30° and 40°.

	Bulk.
30° - - -	100074
31 - - -	100070
32 - - -	100066
33 - - -	100063
34 - - -	100060
35 - - -	100058
36 - - -	100056
37 - - -	100055
38 - - -	100054
39 - - -	100054
40 - - -	100054 *

* Blagden.

From 40° it expands like other substances on being heated (B).

244
Thermometer.

The expansion of bodies by caloric has furnished us with an instrument for measuring the various degrees of it in different substances, we mean the thermometer; and as mercury is the only fluid which expands equally, it is obviously the only proper one for thermometers. The thermometer uniformly used in this article is that of Fahrenheit, except when some other is particularly mentioned.

245
No body without caloric.

2. By means of the thermometer, we learn that there is no body which does not contain caloric, because there is none so cold that it cannot be made colder: and cooling a body is nothing else but abstracting a part of the caloric which it contains.

246
Equilibrium of caloric.

3. Caloric cannot be confined in any body while those in its neighbourhood are colder, but continues to rush out till every thing is reduced to the same temperature. This does not proceed from the attraction of the colder bodies, but from the tendency of caloric to exist everywhere in an equal degree of tension: For when hot bodies are placed in the exhausted receiver of an air-pump, as we learn from Mr Pictet †, or in the Torricellian vacuum, as Count Rumford has shewn us ‡, the caloric leaves them in the same manner, tho' more slowly, and they are equally reduced to the temperature of the surrounding bodies. This property has been called *the equilibrium of caloric*. The only way therefore to confine or accumulate this substance in a body, is to surround it with bodies which are hotter than itself.

† *Sur le Feu*, chap. vi.
‡ *Phil. Transf.* 1786, Part I.

4. The equilibrium of caloric seems evidently to prove

that its particles repel each other. This repulsion will cause them when accumulated in any place to fly off in every direction, and to continue to separate till they are opposed by caloric in other bodies of the same relative density with themselves, which, by repelling them in its turn, compels them to continue where they are. The caloric in bodies therefore is in what has been called by Mr Pictet a state of *tension* (c). Its particles are actuated by a force which would make them separate to an indefinite distance, were they not confined by the opposite force of the caloric which surrounds them. The *equilibrium* therefore depends on the balancing of two opposite forces; the repulsion between the particles of caloric in the body, which tends to diminish the temperature; and the repulsion between the caloric of the body and the surrounding caloric, which tends to raise the temperature. When the first force is greater than the second, as is the case when the temperature of a body is higher than that of the surrounding bodies, the caloric flies off; and the body becomes colder. When the last force is stronger than the first, as is the case when a body is colder than those which are around it, the particles of its caloric are obliged to approach nearer each other, new caloric enters to occupy the space which they had left, and the body becomes hotter. When the two forces are equal, the bodies are said to be of the same temperature, and no change takes place *.

* See *Pictet's Essai sur le Feu*, ch. i.

It is the action of these opposite forces which makes the thermometer a measure of temperature. When applied to any body, it continues to rise or fall till the caloric in it and in the body to which it is applied are of the same tension, and then it remains stationary. The thermometer therefore merely indicates that the temperature of the body to which it is applied is equal to its own. It is obvious that, in order to obtain the real temperature of bodies, the thermometer should be so small that the quantity of caloric, which enters or leaves it, may not materially affect the result.

This property of caloric seems to be the cause of the elasticity of the gases, in which, as we shall shew afterwards, it exists in great quantities. Perhaps it is the cause of elasticity in general; for we have no demonstrative evidence that the particles of elastic bodies repel each other (D), and we are certain that all of them contain caloric. Perhaps also it is owing to this repulsive property of caloric that the particles of no body actually touch each other; for the less caloric we leave in a body, the nearer its particles approach to one another. The expansion of bodies by caloric seems also to depend on the same property. The particles of caloric uniting with those of the body, endeavour to drag them along when they recede from each other. The expansion

(B) There was a curious fact concerning dilatation observed by Mr de Luc. A brass rod which he used as a thermometer became in summer *habitually* longer; that is to say, that after being for some time lengthened by heat, it did not contract by the application of cold to its old length, but continued somewhat longer. In winter the contrary phenomenon took place. After being contracted for some time by cold, it did not return to its old length on the application of heat, but kept somewhat shorter. A leaden rod shewed these effects in a greater degree. Glass has not this quality. De Luc suspects that this property is inversely as the elasticity of bodies. Glass is perfectly elastic, and lead is less elastic than brass.—*Journ. de Phys.* xviii. 369.

(C) The phrase was first used by Mr Volta.

(D) We acknowledge that several philosophers of the first rank, Æpinus for instance, and Bosovich, have supposed that the particles of all bodies both attract and repel each other: but we cannot help thinking it rather improbable (if it be possible) that two such opposite properties should exist together.

Caloric. sion of bodies therefore ought to be inversely as their cohesion, and directly as the tension of the caloric which they contain. This property of caloric seems likewise to afford an explanation of a very curious fact, which was first, we believe, mentioned by De Luc in his Treatise on the Modifications of the Atmosphere, and afterwards ascertained by Dr George Fordyce, that bodies become absolutely lighter by being heated. He took a glass globe three inches in diameter, with a short neck, and weighing 451 grains; poured into it 1700 grains of water from the New river, London, and then sealed it hermetically. The whole weighed $2150\frac{1}{4}$ grains at the temperature of 32° . It was put for twenty minutes into a freezing mixture of snow and salt till some of it was frozen; it was then, after being wiped first with a dry linen cloth, next with clean washed dry leather, immediately weighed, and found to be $\frac{1}{8}$ th of a grain heavier than before. This was repeated exactly in the same manner five different times. At each, more of the water was frozen and more weight gained. When the whole water was frozen, it was $\frac{1}{8}$ ths of a grain heavier than it had been when fluid. A thermometer applied to the globe stood at 10° . When allowed to remain till the thermometer rose to 32° , it weighed $\frac{1}{8}$ ths of a grain more than it did at the same temperature when fluid. We shall shew afterwards that ice contains less caloric than water of the same temperature with it. The balance used was nice enough to mark $\frac{1}{800}$ part of a grain*. Morveau, too, found, much about the same time, that water put into vessels hermetically sealed, weighed more when frozen than when fluid †: and Mr Chauffier found, that two pounds of sulphuric acid were three grains heavier when frozen than after they had recovered their fluidity ‡. Now, if the particles of caloric repel each other, bodies which contain it in great quantities must be somewhat repelled by each other. The more replete therefore that any body is with caloric, the more it will be repelled by the earth, which always contains a great quantity; and this repulsion must in some degree counteract its gravitation. This explanation was first suggested, we believe, by Dr Black.

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Bodies become lighter by being heated,

* Phil. Trans. 1785, Part II. † Journ. de Phys. 1785, Oct. ‡ Journ. de Savans, 1785, P. 493. 249
And why.

250
Caloric moves more readily upwards than downwards

§ See Manometer in this Suppl.

The same property explains another curious fact discovered by Mr Pictet of Geneva, that caloric moves more readily vertically upwards than downwards. He took a tube of tinplate, two inches in diameter and 44 in length, and enclosed in it a bar of copper four lines in diameter and 33 inches in length, which was placed and fixed exactly in its axis. This tube was exhausted of air, by means of an air-pump, till the manometer stood at the height of four lines. It was inclosed in another tube of pasteboard, except about two inches, exactly in the middle, to which place the sun's rays were directed for half an hour by means of a concave mirror. The ends of the copper bar were scooped out into concave hemispheres; and into each of these the bulb of a very sensible thermometer was fixed. The tube was placed vertically. The highest thermometer, which we shall call A, rose to 95° , a hundred and one seconds before the lowest B. The thermometer B rose no high-

er than 95° ; but the thermometer A reached $101,75^{\circ}$. To see whether this difference was owing to the thermometers, the tube was inverted, and consequently the highest thermometer in the former experiment was lowest in this. The thermometer B now rose from 49° to $97,25^{\circ}$ in $2810''$; the thermometer A in $2763''$, or $47''$ sooner than B. It was evident from this result, that the thermometer A was more sensible than the thermometer B by $47''$. If this be subtracted from $101''$, the former difference, it will leave $54''$, as the difference resulting from position. These experiments were repeated with only this difference, that round the ends of the bar and the bulbs of the thermometers (but without touching the bulbs) some folds of oiled paper were wrapped to confine the caloric. The superior thermometer A rose from 50° to $106,25^{\circ}$ in 34 minutes, which was $93''$ sooner than the inferior B: it rose to $110,75^{\circ}$, the thermometer B only to $106,25^{\circ}$. The tube being reversed, the thermometer A, which was now lowest, rose from 46° to $115,25^{\circ}$ in $40' 30''$, or forty seconds sooner than the thermometer B. This subtracted from $93'$, as formerly, leaves $53''$ for the difference of situation. The superior thermometer mounted after the burning-glass was removed $0,45^{\circ}$, remained stationary for $80'$, and after five minutes had only descended $0,45^{\circ}$: the other did not ascend at all; in one minute it descended $0,225^{\circ}$, and in $6' 8''$ it descended $2,47^{\circ}$. In $22' 50''$ the inferior descended $63,725^{\circ}$, the superior $61,475^{\circ}$.* From these experiments, it is obvious that the particles of caloric move somewhat faster, and in somewhat greater quantity, upwards than downwards; owing, doubtless, to the repulsive power of the caloric in the earth. The small quantity of air that remained in the tube may perhaps be supposed sufficient to account for the difference, without allowing any such tendency upwards in caloric. But it is evident from the experiments of the Florentine academicians on the same subject, with tubes full of air, that even when in great abundance, that fluid hardly affected the rising of the superior thermometer: surely then its effect must be altogether imperceptible when so little of it remained; and in the third and fourth experiments the oiled paper prevented any of the heated air from approaching the thermometer.

251
Conducting power of bodies:

5. If we take a bar of iron and a piece of stone of equal dimensions, and putting one end of each into the fire, apply either thermometers or our hands to the other, we shall find the extremity of the iron sensibly hot long before that of the stone. Caloric therefore does not pass through all bodies with the same celerity and ease. The power that bodies have to allow it a passage through them is called their *conducting power*; those that allow it to pass with facility, are called *good conductors*; those through which it passes with difficulty, are called *bad conductors*; and those which do not allow it to pass at all, *non-conductors*.

252
Of wood and charcoal;

It is probable that all solids conduct heat in some degree, at least this is the case with every one at present known. Wood and charcoal are exceeding bad conductors of caloric (E). Count Rumford informs us, that a piece of

(E) This fact merits the attention of chemists. It is obvious, that when metallic oxides are surrounded with charcoal powder, their temperature cannot be raised near so high as it otherwise would be. It is not unlikely that some part of the difficulty which has been experienced in attempting to reduce and fuse several metallic substances may have been owing to this cause.

Caloric of green oak plank was employed to stir the melted metal of which cannons were founding at Munich, and it was often allowed to remain a considerable time in the furnace; yet the caloric had penetrated to so inconsiderable a depth, that at the distance of $\frac{1}{8}$ th of an inch below the surface, the wood did not seem to have been the least affected by it; the colour remained unchanged, and it did not appear to have lost even its moisture*.

* Rumsford's

Essays, ii.

229.

Of glass;

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Of metals;

Glass, when not transparent (F), is also a very bad conductor: and this is the reason that it is so apt to crack on being heated or cooled suddenly; one part of it receiving or parting with its caloric before the rest, expands or contracts, and destroys the cohesion.

Metals are the best conductors of caloric of all the solids hitherto examined. The conducting powers of all, however, are not equal. Dr Ingenhoufz procured cylinders of several metals exactly of the same size, and having coated them with wax, he plunged their ends into hot water, and judged of the conducting power of each by the length of wax-coating melted. From these experiments he concluded, that the conducting powers of the metals which he examined were in the following order †.

† Journ. de Phys. 1789, p. 68.

Silver,	} nearly equal.
Gold,	
Copper,	
Tin,	
Platinum,	
Iron,	} much inferior to the others.
Steel,	
Lead,	

255
Of stones and solids capable of melting.

Next to metals stone seems to be the best conductors; but this property varies considerably in different stones. Bricks are much worse conductors than most stones. All solids capable of being melted become non-conductors the moment they are heated to the melting point: the caloric enters them easily enough, but it remains in them.

256
Whether fluids be conductors of caloric.

A question has lately been agitated among philosophers, Whether fluids be conductors of caloric? No doubt was entertained of their being not only conductors, but good conductors, till the publication of Count Rumford's Essays, in which the author contends, with much plausibility of reasoning, that though fluids carry, they do not *conduct* heat; or, in other words, let it pass freely from one particle to another.

257
What led him to this opinion.

In a set of experiments on the communication of heat, he made use of thermometers of an uncommon size. Having exposed one of these (the bulb of which was near four inches in diameter) filled with alcohol to as great a heat as it could support, he placed it in a window to cool where the sun happened to be shining. Some particles of dust had by accident been mixed with the alcohol: these being illuminated by the sun, became perfectly visible, and discovered that the whole liquid in the tube of the thermometer was in a most rapid motion, running swiftly in opposite directions upwards and downwards at the same time. The *ascending* current occupied the axis, the *descending* current the sides of the tube. When the sides of the tube were cooled by means

of ice, the velocity of both currents was accelerated. It diminished as the liquid cooled; and when it had acquired the temperature of the room, the motion ceased altogether. This experiment was repeated with lintseed oil, and the result was precisely the same. These currents were evidently produced by the particles of the liquid going individually to the sides of the tube, and giving out their caloric. The moment they did so, their specific gravity being increased, they fell to the bottom, and of course pushed up the warmer part of the fluid, which was thus forced to ascend along the axis of the tube. Having reached the top of the tube, the particles gave out part of their caloric, became specifically heavier, and tumbled in their turn to the bottom.

As these internal motions of fluids can only be discovered by mixing with them bodies of the same specific gravity with themselves, and as there is hardly any substance of the same specific gravity with water which is not soluble in it, Count Rumford had recourse to the following ingenious method of ascertaining whether that fluid also followed the same law. The specific gravity of water is increased considerably by dissolving any salt in it; he added, therefore, potash to water till its specific gravity was exactly equal to that of amber, a substance but very little heavier than pure water. A number of small pieces of amber were then mixed with this solution, and the whole put into a glass globe with a long neck, which, on being heated and exposed to cool, exhibited exactly the same phenomena with the other fluids. A change of temperature, amounting only to a very few degrees, was sufficient to set the currents a-flowing; and a motion might at any time be produced by applying a hot or a cold body to any part of the vessel. When a hot body was applied, that part of the fluid nearest it ascended; but it descended on the application of a cold body.

258
Proofs of the non-conducting power of water.

If caloric pass through water only by the internal motion of its particles, as this experiment seems to prove, it is evident that every thing which embarrasses these motions must retard its transmission: and accordingly Count Rumford found this to be the case. He took a large lintseed oil thermometer with a copper bulb and glass tube: the bulb was placed exactly in the centre of a brass cylinder, so that there was a void space between them all around 0,25175 of an inch thick. The thermometer was kept in its place by means of four wooden pins projecting from the sides and bottom of the cylinder, and by the tube of it passing through the cork stopper of the cylinder. This cylinder was filled with pure water, then held in melting snow till the thermometer fell to 32°, and immediately plunged into a vessel of boiling water. The thermometer rose from 32° to 200° in 597". It is obvious that all the caloric which served to raise the thermometer must have made its way through the water in the cylinder. The experiment was repeated exactly in the same manner; but the water in the cylinder, which amounted to 2276 gr. had 192 gr. of starch boiled in it, which rendered it much less fluid. The thermometer now took 1109" to rise from 32° to 200°. The same experiment was again repeated with the same quantity of pure water, having

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(F) When transparent, it transmits caloric.

Caloric. 192 gr. of eiderdown mixed with it, which would merely tend to embarrass the motion of the particles. A quantity of stewed apples were also in another experiment put into the cylinder. The following Tables exhibit the result of all these experiments.

Time the Caloric was in passing into the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through stewed Apples.	Through pure Water.
Therm. rose from 32° to 200° in	1109	949	1096½	597
Therm. rose 80°, viz. from 80° to 160°, in	341	269	335	172

Time the Caloric was in passing out of the Thermometer.

Temperature.	Through the Water and Starch.	Thro' the Water and Eiderdown.	Through stewed Apples.	Through pure Water.
Therm. fell from 200° to 40° in	1548	1541	1749½	1032
Therm. fell 80°, viz. from 160° to 80°, in	468	460	520	277

Now neither the starch nor the eiderdown could produce any alteration in the water except impeding its internal motions; consequently whatever impedes these motions diminishes the conducting power of water. But this could not happen unless every individual particle actually went from the cylinder to the thermometer. Hence it follows that, if liquids be conductors, their conducting power is but small when compared with their carrying power.

All liquids, however, are capable of conducting caloric; for when the source of heat is applied to their surface, the caloric gradually makes its way downwards, and the temperature of every stratum gradually diminishes from the surface to the bottom of the liquid. The increase of temperature in this case is not owing to the carrying power of the liquid. By that power caloric may indeed make its way upwards through liquids, but certainly not downwards. Liquids then are conductors of caloric.

Count Rumford, indeed, has drawn a different conclusion from his experiments. He fixed a cake of ice in the bottom of a glass jar, covered one-fourth inch thick with cold water. Over this was poured gently a considerable quantity of boiling water. Now if water were a non-conductor, no caloric could pass through the cold water, and consequently none of the ice would be melted. The melting of the ice, then, was to determine whether water be a conductor or not. In two hours about half the ice was melted. This one would think, at first sight, a decisive proof that water is a conductor. But the Count has fallen upon a very ingeni-

ous method of accounting for the melting of the ice, without being under the necessity (as he tells us) of renouncing his theory that fluids are non-conductors.

It is well known that the specific gravity of water at 40° is a maximum: if it be either heated above 40°, or cooled down below 40°, its density diminishes. Therefore, whenever a particle of water arrives at the temperature of 40°, it will sink to the bottom of the vessel. Now as the water next the ice was at 32°, it is evident that whenever any part of the hot water was cooled down to 40°, it would sink, displace the water at 32°, come into contact with the ice, and of course melt it. The Count's ingenuity, never without resources, enabled him to prove completely, that the ice employed in his experiment was actually melted in that manner: for when he covered the ice partially with slips of wood, that part which was shaded by the wood was not melted; and when he covered the whole of the ice with a thin plate of tin, having a circular hole in the middle, only the part exactly under the hole was melted. From these facts it certainly may be concluded that the ice was melted by descending currents of water.

But the point to be ascertained, is not whether there were descending currents, but whether water be a conductor or not. Now if water be a non-conductor, by what means was the hot water cooled down to 40°? Not at the surface; for the Count himself tells us, that there the temperature was never under 108°: not by the sides of the vessel; for the descending current in one experiment was exactly in the axis: and it follows irresistibly, from the experiment with the slips of wood, that these descending currents fell equally upon every part of the surface of the ice; which would have been impossible if these currents had been cooled by the side of the vessel. The hot water, then, must have been cooled down to 40° by the cold water below it; consequently it must have imparted caloric to this cold water. If so, one particle of water is capable of absorbing caloric from another; that is, *water is a conductor of caloric*. After the hot water has stood an hour over the ice, its temperature was as follows:

At the surface of the ice	40°
One inch above the ice	80
Two inches	118
Three inches	128
Four inches	130
Seven inches	131

How is it possible to account for this gradual diminution of heat as we approach the ice, if water be a non-conductor? The water, it may be said, gives out caloric at its surface, falls down, and arranges itself according to its specific gravity. If so, how comes it that there is only one degree of difference between the temperature at 4 and at 7 inches above the ice? Thus it appears that the Count's experiment, instead of demonstrating that water is a non-conductor, rather favours the common opinion that it is a conductor.

The Count tried whether oil and mercury be conductors in the following manner: When water was frozen in a glass jar by means of a freezing mixture, Count Rumford observed that the ice first began to be formed at the sides, and gradually increased in thickness; and that the water on the axis of the vessel, which retained its fluidity longest, being compressed by the expansion of the ice, was forced upwards, and when completely frozen,

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Shewn to
be incon-
clusive.

Caloric.

260
Mercury
and oil pro-
ved to be
conductors.

Caloric. frozen, formed a pointed projection or nipple, which was sometimes half an inch higher than the rest of the ice. Upon ice frozen in this manner, he poured olive oil, previously cooled down to 32° , till it stood at the height of three inches above the ice. The vessel was surrounded as high as the ice with a mixture of pounded ice and water. A solid cylinder of wrought iron, $1\frac{1}{4}$ th inch in diameter, and 12 inches long, provided with a hollow cylindrical sheath of thick paper, was heated to the temperature of 210° in boiling water; and being suddenly introduced into its sheath, was suspended from the ceiling of the room, and very gradually let down into the oil, until the middle of the flat surface of the hot iron, which was directly above the point of conical projection of the ice, was distant from it only $\frac{2}{75}$ ths of an inch. The end of the sheath descended $\frac{1}{75}$ th of an inch lower than the end of the hot metallic cylinder. Now it is evident, that if olive oil was a conductor, caloric would pass down through it from the iron and melt the ice. None of the ice, however, was melted; and when mercury was substituted for oil, the result was just the same*; consequently it follows that neither oil nor mercury is a conductor of heat.

* Rumford,
Essay vii.
part ii.
chap. I.

But this experiment is by no means sufficiently delicate to decide the point. If a thermometer be substituted instead of the nipple of ice, it always rises several degrees; whence it follows that, even in this case, caloric passes downwards; so that the experiment is in fact favourable to the supposition that oil and mercury are conductors.

Count Rumford therefore has not proved that fluids are non-conductors of caloric; and that they are in truth conductors, the author of this article ascertained in the following manner: The liquid of which the conducting power was to be examined was poured into a glass vessel till it filled it about half way; then a hot liquid of less specific gravity was poured over it. Thermometers were placed at the surface, in the centre, and at the bottom of the cold liquid; if these rose, it followed that the liquid was a conductor, because the caloric made its way downwards. For instance, to examine the conducting power of mercury, a glass jar was half filled with that liquid metal, and boiling water then poured over it. The thermometer at the surface began immediately to rise, then the thermometer at the centre, and lastly that at the bottom. The first rose to 118° , the second to 90° , and the third to 86° : the first reached its maximum in 1', the second in 15', the third in 25'. The conducting power of water was tried in the same manner with hot oil poured over it; and the result was similar.

Fluids, then, as far as experiments have been made, are conductors of caloric as well as solids; and hence it follows that caloric is capable of making its way thro' all bodies with which we are acquainted. In this respect it differs from all other substances, even from light, which, as far as we know, cannot make its way through all bodies.

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Transmis-
sion of ca-
loric ra-
diant heat.

The motion of caloric through bodies is indeed of two kinds: Through some it seems to move with the same rapidity as through free space; whilst through

others, as we have seen, it moves slowly. When it moves through a body with undiminished velocity, it is said to be *transmitted* through it; and when its velocity is prodigiously diminished, it is said to be conducted. Air, and all transparent bodies hitherto examined, have the property of *transmitting* caloric through them; though some of them, as glass, do not transmit it till after they have combined with a certain proportion of it: and probably no body transmits it unless a greater quantity enter than is capable of combining with it in the state in which the body is placed. The phenomena of the transmission of caloric are exactly similar to the transmission of light, and admit of precisely the same explanation. What Scheele and several other chemists have called *radiant heat*, is nothing else than transmitted caloric; as has been completely proved by Dr Herschel. See *THERMOMETRIC Spectrum* in this Supplement.

6. If equal quantities of water and of mercury be placed at the same distance from a fire, the mercury will become hot much sooner than the water. After a sufficient interval, however, both of them acquire the same temperature. Now caloric flows into all bodies while they continue of a lower temperature than those around them, and it flows with equal rapidity into all bodies of the same conducting powers, as is the case with these two fluids: But if equal quantities of caloric were constantly flowing into the mercury and the water, and yet the water took a longer time to become hot than the mercury, it must require a greater quantity of caloric to raise water to a given temperature than it does to raise mercury. Bodies that require a greater quantity of caloric to raise them to a particular temperature than other bodies require, are said to have a greater *capacity* for caloric. That the capacity for caloric is different in different bodies, was first observed by Dr Black. Dr Irvine afterwards investigated the subject, and Dr Crawford published a great number of experiments on it in his *Treatise on Heat*. Professor Wilcke of Stockholm also discovered the same property of bodies. He called the quantity of caloric necessary to raise the temperature of substances a given number of degrees, their *specific caloric*; a term which we shall also employ, because the phrase *capacity for caloric* is liable to a great deal of ambiguity, and has introduced confusion into this subject (F). If two substances of unequal temperatures, as water at 100° and alcohol at 50° , be mixed together, the mixture will be of a temperature different both from that of the water and the alcohol, the water will give out caloric to the alcohol till both are reduced to the same temperature. Now if it requires just as much caloric to raise alcohol a certain number of degrees as it does to raise water the same number, that is, if these two fluids are of the same specific caloric, it is evident that the temperature of the mixture will be just 75° ; for as soon as the water has given out 25° of caloric, the alcohol has acquired 25° , consequently both will be reduced to the same temperature, and will remain stationary; but if the specific caloric of the water be greater than that of the alcohol, the temperature of the mixture will be higher than 75° ; for 25° of

Caloric.

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Specific ca-
loric of bo-
dies, what.

(F) The term *specific caloric* has been used in a different sense by Seguin. He used it for the *whole caloric* which a body contains.

of caloric in that case would raise alcohol more than 25°. If the specific-caloric of water be so much greater than that of alcohol, that what raises water 20° will raise alcohol 30°; then the temperature after mixture will be 80°, because when the water has given out 20°, the alcohol will have risen 30°, and of course both will be of the same temperature. On the contrary, if the specific caloric of alcohol were greater than that of water, the temperature of the mixture would be under 75°. If the same quantity of caloric that raised alcohol 20° raised water 30°, then the temperature of the mixture would be 70°. Thus the ratios of the specific caloric of bodies may be discovered by mixing them together at different temperatures.

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Experiments on
specific caloric by
Wilcke,

The first set of experiments on this subject, in point of time, were probably those of Mr Wilcke. They were first published in the Stockholm Transactions for 1781, but had been made long before. The manner in which they were conducted is exceedingly ingenious, and they furnish us with the specific caloric of many of the metals. The metal on which the experiment was to be made was first weighed accurately (generally one pound was taken), and then being suspended by a thread, was plunged into a large vessel of tinfoil, filled with boiling water, and kept there till it acquired a certain temperature, which was ascertained by a thermometer. Into another small box of tinfoil exactly as much water at 32° was put as equalled the weight of the metal. Into this vessel the metal was plunged, and suspended in it so as not to touch its sides or bottom; and the degree of heat, the moment the metal and water were reduced to the same temperature, was marked by a very accurate thermometer. He then calculated what the temperature would have been if a quantity of water equal in weight to the metal, and of the same temperature with it, had been added to the ice-cold water instead of the metal.

Let M be a quantity of water at the temperature C , m another quantity at the temperature c , and let their common temperature after mixture be x ; according to a rule demonstrated long ago by Richman, $x = \frac{MC + mc}{M + m}$. In the present case the quantities of water are equal, therefore M and m are each = 1; C , the temperature of the ice-cold water = 32: therefore $\frac{MC + mc}{M + m} = \frac{32 + c}{2}$. Now c is the temperature of the metal.

Therefore if 32 be added to the temperature of the metal, and the whole be divided by 2, the quotient will express the temperature of the mixture, if an equal weight of water with the metal, and of the same temperature with it, had been added to the ice-cold water instead of the metal.

He then calculated what the temperature of the mixture would have been, if, instead of the metal, a quantity of water of the same temperature with it, and equal to the metal in bulk, had been added to the ice-cold water. As the weights of the ice-cold water and the metal are equal, their volumes are inversely as their specific gravi-

ties. Therefore the volume of ice-cold water is to a quantity of hot water equal in volume to the metal, as the specific gravity of the metal to that of the water. Let M = volume of cold water, m = volume of hot water, g = specific gravity of the metal, 1 = specific gravity of water; then $m : M :: 1 : g$; hence

$m = \frac{M}{g} = (M \text{ being made } = 1) \frac{1}{g}$. Substituting this value of m in the formula, $\frac{MC + mc}{M + m} = x$, in

which $M = 1$ and $C = 32$, x will be $= \frac{32g + 1}{g + 1}$.

Therefore if the specific gravity of the metal be multiplied by 32, and the temperature of the metal be added, and the sum be divided by the specific gravity of the metal + 1, the quotient will express the temperature to which the ice-cold water would be raised by adding to it a volume of water equal to that of the metal, and of the same temperature with it.

He then calculated how much water at the temperature of the metal it would take to raise the ice-cold water the same number of degrees which the metal had raised it. Let the temperature to which the metal had raised the ice-cold water be = N , if in the formula $\frac{MC + mc}{M + m} = x$, x be made = N , $M = 1$, $C = 32$, m will be $= \frac{N - 32}{c - N}$. Therefore if from the temperature to which the ice-cold water was raised by the metal 32 be subtracted, and if from the temperature of the metal be subtracted the temperature to which it raised the water, and the first remainder be divided by the last, the quotient will express the quantity of water of the temperature of the metal which would have raised the ice-cold water the same number of degrees that the metal did.

Now $\frac{N - 32}{c - N}$ expresses the specific caloric of the metal, that of water being = 1. For (neglecting the small difference occasioned by the difference of temperature) the weight and volume of the ice-cold water are to the weight and volume of the hot water as 1 to $\frac{N - 32}{c - N}$, and the number of particles of water in each are in the same proportion. But the metal is equal in weight to the ice-cold water; it must therefore contain as many particles of matter; therefore the quantity of matter in the metal must be to that in the hot water as 1 to $\frac{N - 32}{c - N}$. But they give out the same quantity of caloric; which, being divided equally among their particles, gives to each particle a quantity of caloric inversely as the bulks of the metal and water; that is, the specific caloric of the water is to that of the metal as 1 to $\frac{N - 32}{c - N}$ (G).

We shall now give a specimen or two of his experiments, and the calculations founded on them, as above described.

(G) We have altered all these formulas to make them correspond with Fahrenheit's thermometer. They are a good deal simpler when the experiments are made with Celsius's thermometer, as Mr Wilcke did. In it the freezing point is zero; and consequently instead of 32 in the formula, 0 is always substituted.

GOLD. Specific Gravity 19,040.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raised, the water at 32°.	Temperature to which it would have been raised by a quantity of water equal in weight and heat to the metal.	Temperature to which it would have been raised by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{1}{c-N} = \frac{1}{c-N}$, the numerator being 1.
1	163,4°	38,3°	97,7°	38,555°	19,857
2	144,5	37,4	88,25	37,58	19,833
3	127,4	36,5	79,7	36,68	20,500
4	118,4	36,05	75,2	36,15	20,333
5	103,1	35,6	65,75	35,42	18,750
6	95	34,45	63,5	35,06	19,000

Mean 19,712

LEAD. Specific Gravity 11,456.

Number of experiments.	Temperature of the metal.	Temperature to which the metal raised, the water at 32°.	Temperature to which the water would have been raised by a quantity of water equal in weight and heat to the metal.	Temperature to which the water would have been raised by water equal in bulk and temperature to the metal.	Denominator of the fraction $\frac{1}{c-N}$
1	186,8	38,3	109,4	44,425	23,571
2	181,40	37,85	106,7	43,473	24,538
3	165,2	37,4	98,6	42,692	23,666
4	163,4	37,4	97,7	42,548	23,333
5	136,4	36,5	84,2	40,344	22,200
6	131	36,05	81,5	39,947	24,700
7	126,5	36,05	79,25	39,585	22,333
8	107,6	35,15	69,8	38,339	23,000
9.	94,1	34,7	63,05	36,985	22,000

Mean 23,515

It is needless to add, that the last column marks the denominator of the specific caloric of the metal, the numerator being always 1, and the specific caloric of water being 1. Thus the specific caloric of gold is

$\frac{1}{19,712}$. In exactly the same manner, and by taking a mean of a number of experiments at different temperatures, did Mr Wilcke ascertain the specific caloric of a number of other bodies. He ascertained at the same time, that the specific caloric of a body did not vary with the temperature, but continued always the same. This will appear evident from the experiments on gold and lead above exhibited.

264
Crawford,

Next, in point of time, and not inferior in ingenious contrivances to ensure accuracy, were the experiments of Dr Crawford, made by mixing together bodies of different temperatures. These were published in his *Treatise on Heat*.

265
Lavoisier
and La
Place,

Several experiments on the specific caloric of bodies were made also by Lavoisier and De la Place, which, from the well-known accuracy of these philosophers, cannot but be very valuable.

Their method was exceedingly simple and ingenious;

it was first suggested by De la Place. An instrument was contrived, to which Lavoisier gave the name of *calorimeter*. It consists of three circular vessels nearly inscribed into each other, so as to form three different apartments, one within the other. These three we shall call the *interior*, *middle*, and *external cavities*. The interior cavity *ffff* (see section of the instrument fig. 4.), into which the substances submitted to experiment are put, is composed of a grating or cage of iron wire, supported by several iron bars. Its opening or mouth *LM* is covered by the lid *HG*, which is composed of the same materials. The middle cavity *bbbb* is filled with ice. This ice is supported by the grate *mm*, and under the grate is placed a sieve. The external cavity *aaa* is also filled with ice. We have mentioned already, that no caloric can pass through ice. It can enter ice, indeed, but it remains in it, and is employed in melting it. The quantity of ice melted, then, is a measure of the caloric which has entered into the ice. The exterior and middle cavities being filled with ice, all the water is allowed to drain away, and the temperature of the interior cavity to come down to 32°. Then the substance, the specific caloric of which is to be ascertained, is heated a certain number of degrees, suppose to 212°, and then put into the interior cavity enclosed in a thin vessel. As it cools, it melts the ice in the middle cavity. In proportion as it melts, the water runs through the grate and sieve, and falls through the conical funnel *ccd* and the tube *xy* into a vessel placed below to receive it. The external cavity is filled with ice, in order to prevent the external air from approaching the ice in the middle cavity and melting part of it. The water produced from it is carried off through the pipe *ST*. The external air ought never to be below 32°, nor above 41°. In the first case, the ice in the middle cavity might be cooled too low; in the last, a current of air flows through the machine and carries off some of the caloric. By putting various substances at the same temperature into this machine, and observing how much ice each of them melted in cooling down to 32°, it was easy to ascertain the specific caloric of each. Thus, if water, in cooling from 212 to 32, melted one pound of ice, and mercury, 0,29 of a pound; the specific caloric of water was one, and that of mercury, 0,29. This appears by far the simplest method of making experiments on this subject; and must also be the most accurate, provided we can be certain that all the melted snow flows into the receiver. But from an experiment of Mr Wedgewood, one would be apt to conclude that this does not happen. He found that the melted ice, so far from flowing out, actually froze again, and choked up the passage.

A table of the specific caloric of various bodies was likewise drawn up by Mr Kirwan, and published by Mawellan in his *Treatise on Heat*.

From all these sources we have drawn up the following table, which exhibits at one view the specific caloric of those bodies on which experiments have hitherto been made.

We have added to it a column, expressing the specific caloric of equal bulks of the same bodies; which seems to be a more accurate way of considering this subject, and indeed the only way in which the phrase *capacity for caloric* is intelligible. This column was formed by multiplying the specific caloric of equal weights of the various substances into their respective specific gravities.

Result of these experiments.

TABLE

TABLE of the Specific Caloric of Various Bodies, that of Water being = 1,0000 (H).

Bodies.	Specific Gravity.	Specific of equal Weight.	Caloric of equal Volumes.	Bodies.	Specific Gravity.	Specific of equal Weight.	Caloric of equal Volumes.
I. GASES*.				III. SOLIDS.			
Hydrogen gas - -	0,000094	21,4000	0,00214	Ice † - - - -		0,9000	
Oxygen gas - - -	0,0034	4,7490	0,006411	Ox-hide with the hair* -		0,787	
Common air - - -	0,00122	1,7900	0,002183	Lungs of a sheep* - -		0,769	
Carbonic acid gas -	0,00183	1,0459	0,001930	Lean of ox-beef* - -		0,7400	
Steam - - - - -		1,5500		Rice* - - - - -		0,5050	
Azotic gas - - -	0,00120	0,7036	0,000952	Horfe beans* - - -		0,5020	
II. LIQUIDS.				Dust of the pine tree* -		0,5000	
Water - - - - -	1,0000	1,0000	1,0000	Pease* - - - - -		0,4920	
Carbonat of ammonia †		1,851		Wheat* - - - - -		0,4770	
Arterial blood* - -		1,030		Barley* - - - - -		0,4210	
Cows milk* - - -	1,0324	0,9999	1,0322	Oats* - - - - -		0,4160	
Sulphuret of ammonia †	0,818	0,9940	0,8130	Pitcoal* - - - - -		0,2777	
Venous blood* - -		0,8928		Charcoal* - - - - -		0,2631	
Solution of brown sugar †		0,8600		Chalk* - - - - -		0,2564	
Nitric acid † - - -		0,844		Rust of iron* - - -		0,2500	
Sulphat of magnesia 1 } †		0,844		White oxide of antimony washed* - - - -		0,2270	
Water 8 } †		0,832		Oxide of copper nearly freed from air* - -		0,2272	
Common salt 1 } †		0,832		Quicklime (c) - - -		0,2199	
Water 8 } †		0,8167		Stoneware † - - -		0,195	
Nitre 1 } †		0,8167		Agate** - - - - -	2,648	0,195	0,517
Water 8 } †		0,779		Crystal † - - - -	3,189?	0,1929	0,6151
Muriat of ammonia 1 } †		0,779		Cinders* - - - - -		0,1923	
Water 1,5 } †		0,765		Swedish glass** - -	2,386	0,187	0,448
Tartar 1 } †		0,765		Ashes of cinders* -		0,1885	
Water 237,3 } †		0,759	1,2216	Sulphur † - - - -	1,99	0,183	0,3680
Solution of potash †	1,346	0,759	1,2216	Flint glass † - - -	3,3293	0,174	0,5792
Sulphat of iron 1 } †		0,734		Rust of iron nearly freed from air* - - - -		0,1666	
Water 2,5 } †		0,728		White oxide of antimony ditto* - - -		0,1666	
Sulphat of soda 1 } †		0,728		Ashes of the elm* -		0,1402	
Water 2,9 } †		0,710	0,6498	Oxide of zinc nearly freed from air* - - - -		0,1369	
Oil of olives † - -	0,9153	0,710	0,6498	Iron (d) - - - - -	7,876	0,1264	0,993
Ammonia † - - -	0,997	0,7080	0,7041	Brass (d) - - - - -	8,358	0,1141	0,971
Muriatic acid † -	1,122	0,6800	0,763	Copper (d) - - - -	8,784	0,1121	1,027
Sulphuric acid 4 } †		0,6631		Sheet iron † - - -		0,1099	
Water 5 } †		0,649		Oxide of lead and tin* -		0,102	
Alum 1 } †		0,649		Gun-metal - - -		0,1100	
Water 4,45 } †		0,6181		White oxide of tin nearly free from air* - -		0,0990	
Nitric acid 9 1/2 } †		0,6181		Zinc (d) - - - - -	7,154	0,0981	0,735
Lime 1 } †		0,646		Ashes of charcoal* -		0,0909	
Water 3 } †		0,6021	0,4993	Silver** - - - - -	10,001	0,082	0,833
Alcohol* - - - -	0,8371	0,6021	0,4993	Yellow oxide of lead nearly freed from air* -		0,0680	
Sulphuric acid § -	1,840	0,5968	1,120	Tin (e) - - - - -	7,380	0,0661	0,444
Nitrous acid † -	1,355	0,576	0,780	Antimony (d) - - -	6,107	0,0637	0,390
Linseed oil † - -	0,9403	0,528	0,4964	Gold** - - - - -	19,040	0,050	0,966
Spermaceti oil* -		0,5000		Lead (e) - - - - -	11,456	0,0424	0,487
Oil of turpentine †	0,9910	0,472	0,4132	Bismuth** - - - -	9,861	0,043	0,427
Vinegar † - - - -		0,3870	0,3966				
Lime 9 } †		0,3346					
Water 16 } †		0,3100	4,123				
Mercury ¶ - - - -	13,568	0,3100	4,123				
Distilled vinegar †		0,1030	0,1039				

7. If

(H) The specific caloric of the substances marked * was ascertained by Dr Crawford, those marked † by Mr Kirwan, ‡ by Lavoisier and La Place, ** by Wilcke, || by Count Rumford, § Is the mean of Crawford, Kirwan, and Lavoisier; ¶ mean of Lavoisier and Kirwan; (c) mean of Crawford and Lavoisier; (d) mean of Wilcke and Crawford; (e) mean of Wilcke, Crawford, and Kirwan.

Caloric.
468
Latent ca-
loric, or

7. If a quantity of ice, at a low temperature, suppose at 20° , be suspended in a warm room, it will become gradually less cold, as may be discovered by means of a thermometer, till it reaches the temperature of 32° ; but there it stops. The ice, however, dissolves slowly; and at the end of several hours, when it is all just melted, the thermometer still stands at 32° . After this it begins to rise, and soon reaches the temperature of the room. Here the ice continues for several hours colder than the air around it. Caloric must then be continually flowing into it; yet it does not become hotter: it is changed, however, into water. Ice, therefore, is converted into water by a quantity of caloric uniting with it. This caloric has been called *latent caloric*, because its presence is not indicated by the thermometer. It might, perhaps with more propriety, as Professor Pictet observes*, be called *caloric of fluidity*; for there are other cases in which caloric exists in bodies without raising their temperature. This very important discovery was made by Dr Black as early as 1757, and seems to have led the way to all the subsequent discoveries in this part of chemistry, which have almost completely changed the appearance of the science: for the discovery that caloric may exist in bodies while the thermometer cannot indicate its presence, is one of the strongest links in the chain of facts by which the nature of combustion was ascertained.

The caloric which unites with ice, and renders it fluid, appears again during the act of *freezing*. If a quantity of water be carried into a room where the temperature is below the freezing point, suppose at 20° , it cools gradually down to 32° ; but it becomes no colder till it is all frozen, which takes up some time. The moment it is all converted into ice, it begins again to cool, and soon reaches the temperature of the room. In this case, the water is surrounded by a cold atmosphere; it must therefore be giving out caloric constantly; yet it does not become colder till it is all frozen, that is to say, till it has lost all its *caloric of fluidity*.

Dr Black proved, by a very accurate experiment, that the quantity of *caloric of fluidity* is sufficient to raise the same quantity of water 140° .

All solids become fluid by absorbing a quantity of caloric. Landriani proved that this is the case with sulphur, alum, nitre, and several of the metals†; and it has been found to be the case with every substance hitherto examined. Fluidity, therefore, is owing to a union between the solid and a certain quantity of caloric.

The late Dr Irvine of Glasgow advanced a theory on this subject different from that of Dr Black. The specific caloric of water being greater than that of ice, it requires a greater quantity of caloric to raise it to a given temperature than it does to raise ice. The caloric does not therefore become *latent*; it only seems to do so from the greater specific caloric of water. This

theory was zealously adopted by Dr Crawford. Dr Black observed very justly, that it did not account for the production of fluidity at all. The specific caloric of water is indeed greater than that of ice; but how is the ice converted into water? This is an objection which the advocates for Dr Irvine's, or Dr Crawford's, theory (as it has been improperly called) will not easily answer. Let us now examine whether this theory accounts for the apparent loss of caloric. It follows from Mr Kirwan's experiments, that the specific caloric of water is to that of ice as 10 to 9 (1). Dr Black proved, that as much caloric entered the ice as would have raised it, had it been water, 140° . Let us suppose that it would only have raised the ice 240° ; in that case the melted ice ought to have been of the temperature of 158° , for $10 : 9 :: 140 : 126$; but it was only 32° : Therefore 126° of caloric have disappeared, and cannot be accounted for by the change of specific caloric. Nor can the accuracy of Dr Black's experiment be suspected: it has been repeated in every part of the world, and varied in every possible way. We cannot doubt, therefore, that caloric unites with substances, and causes them to become fluid, or that *there is in fact a caloric of fluidity different from specific caloric*.

Water also is converted into *steam* by uniting with caloric. Dr Black put an iron vessel, containing four ounces of water at the temperature of 53° , upon a cast-iron table which was red hot. The water rose to the boiling point in three minutes; but it did not afterwards become any hotter. It evaporated, however, in 18 minutes; and the steam was precisely at the temperature of 212° . During the first three minutes, it received 159° of caloric, and as much must have been entering it during every three minutes while the evaporation continued, as the temperature was always much lower than that of the table. This caloric, instead of raising the temperature of the water, was employed in converting it into steam. There is also, therefore, a quantity of latent caloric in steam. It might, as Mr Pictet observes, be called, with propriety, *caloric of evaporation*. This caloric appears again if the steam be condensed. If it be made to pass, for instance, through a pipe surrounded with cold water, it is condensed in the pipe, and drops out from it in the form of water. The caloric of the steam enters into the water around the pipe, and the quantity of it in degrees may be discovered by the number of degrees which it raises that water. By an experiment of this kind, it was proved, that the caloric of evaporation would be sufficient to heat water red hot, were it employed only in raising its temperature, instead of converting it into steam. It is therefore at least equal to 800° . Mr Watt shewed afterwards that it was 920° .

Even spontaneous evaporation, as Dr Black first observed, is owing to the same cause: and this explains why bodies cool when water is evaporated from their surface;

(1) We do not know how this was ascertained: Not by mixing water and ice surely; because that would be taking for granted the thing to be proved; because it would give a very different result; and what is still worse, the specific caloric in that case would differ according to the temperature and the quantity of water. To give an instance: Mr Gadolin concludes, from 180 experiments made by mixing hot water and ice, that the specific caloric of ice is to that of water only as 1 to 2*; and had he varied the quantities and the temperatures, he might have obtained several other ratios.

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Caloric of
fluidity.
* Sur le Feu,
ch. I.

† Four. de
Phys. xxvi.

* Ann de
Chim. xi.
27.

270
Caloric of
evaporation

Caloric.

surface; a fact which has been long known, and which has been employed in warm countries to diminish the temperature of liquids, and even to convert them into ice (κ). That water is evaporated by uniting with caloric, and not by solution in air, has been proved very completely by De Luc in his Treatise on Meteorology.

The evaporation of alcohol, ether, and every other substance on which experiments have been made, has been found owing to the same cause. Bodies, therefore, are converted into vapour by uniting with caloric.

271
Real zero,
what.

8. If caloric, as has been shewn, exists in bodies at the lowest temperature which we are able to procure, and if it exists in them while the thermometer cannot discover its presence—is there any method of ascertaining its absolute quantity in bodies? At what degree would a thermometer stand (supposing the thermometer capable of measuring so low) were the body to which it is applied totally deprived of caloric? or what degree of the thermometer corresponds to the real zero?

The first person (as far as we know), at least since

men began to think accurately on the subject, who conceived the possibility of determining this question, was Dr Irvine of Glasgow. He invented a theorem, in order to ascertain the real zero, which has, we know not for what reason, been ascribed by several writers to Mr Kirwan. He took it for granted (and the fact is proved by all the experiments hitherto made) that the specific caloric of bodies continued the same in every degree of temperature, as long as they remained in the same state, that is to say, as long as they continued either solid or fluid or in a state of vapour; but that the specific caloric of the same body while solid was less than while fluid, and less while fluid than while in a state of vapour. He took it for granted, too, that the 140 degrees of caloric which entered ice during its solution without raising its temperature, entered merely in consequence of the increased specific caloric of the water, and that they were exactly proportional to this increased specific caloric. He took it for granted, likewise, that the specific caloric of bodies was proportional to

Caloric.
272
Irvine's
theorem to
discover it.

(κ) Galen informs us, that the ancient Egyptians were accustomed to put water previously boiled into earthen jars, and expose them all night on the upper part of their houses to the air. Before sunrise these vessels were put into the ground, moistened on the outside with water, and then surrounded with fresh plants; by which means the water was preserved cool during the whole day. *Comment. in lib. vi. Hippoc. de morbis vulgar. 4. 10. p. 396.*

By a similar process, water, in the East Indies, is converted into ice.

The following singular passage, which has been pointed out to us by the ingenious Dr Barclay, lecturer on anatomy in Edinburgh, furnishes a striking proof that the ancients were led, by a very different method of reasoning, to deduce, from their philosophical theory of the four elements, conclusions concerning the nature of heat not very different from those of the moderns.

“ Sic enim res se habet, ut omnia, quæ alantur et quæ crescant, contineant in se vim caloris; sine qua neque ali possent nec crescere. Nam omne, quod est calidum et igneum, cietur et agitur motu suo: quod autem alitur et crescit, motu quodam utitur certo et æquabili; qui quandiu remanet in nobis, tamdiu sensus et vita remanet: refrigerato autem et extincto calore, occidimus ipsi et extinguimur. Quod quidem Cleanthes his etiam argumentis docet, quanta vis insit caloris in omni corpore: negat enim ullum esse cibum tam gravem, quia is nocte et die concoquitur; cujus etiam in reliquiis insit calor his quas natura respicit. Jam verò venæ et arteriæ micare non desinunt, quasi quodam igneo motu; animadversumque sæpe est, cum cor animantis alicujus evulsam ita mobiliter palpitaret, ut imitaretur igneam celeritatem. Omne igitur quod vivit, sive animal sive terra editum, id vivit propter inclusum in eo calorem. Ex quo intellegi debet, eam caloris naturam, vim habere in se vitalem per omnem mundum pertinentem. Atque id facilius cernemus, toto genere hoc igneo, quod tranat omnia, subtilius explicato. Omnes igitur partes mundi (tangam autem maximas) calore fultæ sustentantur. Quod primum in terrena natura perspicui potest. Nam et lapidum conflictu atque tritu elici ignem videmus; et recuti fossione

— terram fumare calentem;

atque etiam ex puteis jugibus aquam calidam trahi, et id maxumè fieri temporibus hibernis, quòd magna vis caloris, terræ continueatur cavernis; eaque hieme fit densior; ob eamque causam, calorem insitum in terris continueatur arctius.

“ Longa est oratio, multæque rationes, quibus doceri possit, omnia, quæ terra concipiat, semina, quæque ipsa ex se generata stirpibus infixæ contineat, ea temperatione caloris et oriri et auferere. Atque aquæ etiam admixtum esse calorem, primum ipse liquor, tum aquæ declarat effusio: quæ neque congelaretur frigoribus, neque nive pruinaque concreveret, nisi eadem se admixto calore liquefacta et dilapsa diffunderet. Itaque et aquilonibus reliquisque frigoribus durefcit humor: et idem vicissim mollitur tepescitque et tabescit calore. Atque etiam maria agitata ventis ita turgescunt, ut intellegi faciliè possit, in tantis illis humoribus esse inclusum calorem. Nec enim ille externus et adventicius habendus est tepor, sed ex intimis maris partibus agitatione excitatus: quod nostris quoque corporibus continget, cum motu atque exercitatione recalescunt. Ipse verò aër, qui natura est maxumè frigidus, minime est expers caloris. Ille verò et multo quidem calore admixtus est: ipse enim oritur ex respiratione aquarum: earum enim quasi vapor quidam aër habendus est. Is autem existit motu ejus caloris, qui aquis continetur. Quam similitudinem cernere possumus in his aquis, quæ effervescent subditis ignibus. Jam verò reliqua quarta pars mundi, ea et ipsa tota natura fervida est, et ceteris naturis omnibus salutarem impertit et vitalem calorem. Ex quo concluditur, cum omnes mundi partes sustentantur calore, mundum etiam ipsum simili parique natura in tanta diuturnitate fervari: eoque magis, quòd intellegi debet, calidum illud atque igneum ita in omni fufum esse natura, ut in eo insit procreandi vis et causa gignendi, à quo et animantia omnia, et ea quorum stirpes terra continentur, et nasci sit necesse et auferere. *Cicero de natura Deorum, lib. ii. c. 9. et 10.*

Caloric. to their *absolute caloric*, or to all the caloric which existed in each.

On these data he reasoned in the following manner: Let A be a body in a state of fluidity; B the same body in a state of solidity. If the specific caloric of A and of B be known, and if it be known how many degrees the caloric, disengaged during the change of B into A, would raise the temperature of A, it may be found by an easy process how many degrees all the caloric contained in B would raise the temperature of A; and the sum of these two numbers will represent in degrees the whole quantity of caloric in A: for the quantity of caloric in A must be just equal to the caloric in B, together with what entered into it in passing from the state of B to that of A. Let the specific caloric of A be 6, that of B 1; and let the quantity of caloric disengaged during the change of A into B be sufficient to raise the temperature of A 500°. If the specific caloric be proportional to the absolute caloric, it must contain exactly 6 times as much caloric as B. The 500° which entered into A when it changed its state, must be just 5 times as great as all the caloric of B; because when added to the caloric of B, it formed the caloric in A, which is just 6 times as great as the caloric in B. Therefore to discover the caloric in B, we have only to divide 500 by 5, or, which is the same thing, to state this proportion 6—1 : 500 : 1 : 100. The caloric in B, therefore, in this case is just as much as would raise the temperature of A 100°. Therefore, if to 100°, the caloric of B, be added 500°, = caloric disengaged in the passage of A to B, this will give 600°, = to all the caloric in A. Therefore, in all cases, the difference between the numbers expressing the specific caloric of the solid and fluid, is to the number expressing the specific caloric of the solid, as the quantity of caloric disengaged during the passage of the fluid into a solid is to the quantity of caloric in the fluid.

Dr Crawford embraced this theorem; and concluded, from a number of experiments made on purpose to ascertain the fact, that the real zero was 1268° below 0, or 1300° below the freezing point.

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Examined. This subject deserves to be considered with attention. If this theorem in fact furnishes us with the real zero, it is one of the most important discoveries which has ever been made in chemistry; but if it proceeds on erroneous principles, it will only involve us in endless mazes of error and absurdity.

In the first place, if the real zero has any meaning at all, it must signify the degree to which the thermometer (supposing it could be used) would sink on being applied to a body which contained no heat. It must therefore be a fixed point; and were the theorem which we are examining well founded, experiments upon every different substance, if conducted with accuracy, would lead to the same result. Let us see whether this be the case.

From Dr Crawford's experiments, it follows, as we have seen, that the real zero is 1268° below 0.

Mr Kirwan, from comparing the specific caloric of water and ice, fixed the real zero at 1048° below 0.

From the experiments of Lavoisier and Laplace on a mixture of water and quicklime, in the proportion of 9 to 16, it follows, that the real zero is 2736° below 0.

From their experiments on a mixture of 4 parts of sulphuric acid and 3 parts of water, it follows, that the real zero is 5803,4° below 0.

Their experiments on a mixture of 4 parts of sulphuric acid and 5 of water, place it at 2073,3° below 0.

Their experiments on 9½ parts of nitric acid and 1 of lime, place it at $\frac{1889}{-0,01783}$ below 32°*.

These results differ from one another so enormously, and the last of them, which makes the real zero a negative quantity, is so absurd, that they are alone sufficient to convince us that the data on which they are founded are not true. Should it be said that their difference is not owing to any defect in the theorem, but to inaccuracies in making the experiments—we answer, that the theorem itself is founded on similar experiments; and if experiments of this nature, even in the hands of the most accurate chemists, cannot be freed from such enormous errors, how can we depend on any consequences deduced from them? and where, then, is our evidence for the truth of the theorem?

But, farther, there is no proof whatever that the specific caloric of bodies is proportional to their absolute caloric. The specific caloric of iron is greater than that of water, or even azotic gas; yet surely it is very improbable that iron contains more absolute caloric than either of these substances.

If the specific caloric of bodies has any meaning at all, it can only be, that the same quantity of caloric raises the temperature of one body a greater number of degrees than it does another. When we say that the specific caloric of A is = 6, and that of B = 1, what do we mean, unless that the quantity of caloric which raises B 6° raises A only 1°, or that what raises B 60° or 600°, raises A only 10° or 100°? When we say that the specific caloric of water is 10, and that of ice 9, do we not mean, that the quantity of caloric which raises the ice 10° or 100°, raises water only 9° or 90°? Yet during the change of ice into water, 140° of caloric enter it without raising its temperature; a quantity greater than what can be accounted for by the difference of specific caloric by 126°. The quantity that disappears, therefore, is *not* proportional to the difference of specific caloric; and therefore any theory which depends on that supposition cannot be well founded. When water is converted into steam, 800° of caloric disappear, yet the specific caloric of steam is 10, and that of water, according to Dr Crawford's own experiments, only as 155 to 100: so that no less than 283° disappear, which cannot be accounted for according to this theory.

Dr Irvine's theorem, therefore, is insufficient for ascertaining the real zero; and hitherto no method has been discovered which can solve this problem.

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And found
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Caloric ex-
ists in bo-
dies
9. If there be no body without caloric, if it exists in different quantities in different bodies, even when their temperatures are the same, and while the thermometer cannot indicate its presence—in what state does it exist in them? We cannot surely suppose that it is contained by them just as water is contained by a vessel of wood or metal, or that they are filled with it in the same manner that a hollow globe of tinplate perforated with holes is filled with water when it is plunged into a quantity of that liquid; or that bodies are filled with caloric merely because they are immersed in an ocean of caloric. Were that the case, the specific and absolute caloric of bodies would always be proportional; and they would of necessity be inversely as the specific gravity of the respective bodies; because the less the specific gravity, the more room would be left for the particles

Caloric.

ticles of caloric. But this is by no means the case: the specific gravity of iron, for instance, is greater than that of tin, yet the specific caloric of iron is more than double that of tin: the specific gravity of oxygen gas is greater than that of common air, yet the specific caloric of the first of these substances is more than three times as great as that of the other. There must be something, therefore, in bodies themselves quite different from, and unconnected with, the vacuities between their particles, which disposes some to admit more caloric than others. And what can that be but a disposition in different bodies to unite with a greater or a smaller quantity of caloric, and to retain it with more or less firmness according to their affinity for it? Dr Black pointed out, long ago, by discovering latent heat, that caloric unites with bodies; and this seems to be the only real key for unfolding the actions of this extraordinary substance. If caloric be matter, can it be destitute of that property which all other matter possesses, we mean attraction? And if it possesses attraction, must it not combine with those bodies that attract it just as other bodies combine with each other? Must there not be formed a chemical union between caloric and other substances, which can only be broken by chemical means, by presenting a third body which has a greater affinity either for the caloric or the body to which it is united, than they have for each other?

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In a state of
chemical
combina-
tion.

277
Proved to
be the case
in liquids,
vapours,

That it unites chemically with some bodies, at least, cannot be doubted, as we have shewn already, that whenever a solid is converted into a liquid, a quantity of caloric enters, and remains in it; and that both the solid and the caloric lose their characteristic properties. This is precisely what takes place in every chemical union. All liquids, therefore, consist of solids combined with caloric. We have seen, too, that liquids are converted into vapours by the very same process. There are therefore, at least, two very large classes of bodies, liquids and vapours, in which we are certain that caloric exists in a state of chemical combination.

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And gases;

There is another class of bodies which resembles vapours in almost all their properties: these are the gases. Like them, they are invisible and elastic, and capable of indefinite expansion. Is it not probable, then, that the gases also, as well as the vapours, owe their properties to caloric? that they also consist of their respective bases combined with that subtle substance? This probability has been reduced to certainty by an experiment of Lavoisier. By adding two tubes to the calorimeter formerly described, he contrived to make known quantities of air to pass through the interior cavity, and to support combustion. He found, that when a pound of oxygen gas was made to combine in this manner with phosphorus, as much caloric was disengaged as melted $87\frac{1}{2}$ pounds of ice*. Now every pound of ice absorbs as much caloric in the act of melting as is sufficient to raise a pound of water 140° . Therefore the whole caloric disengaged was sufficient to raise a pound of water 1225° . All this could not have come from the phosphorus, because it had been converted into a liquid, and must therefore have absorbed instead of parted with caloric, and because the quantity of caloric disengaged in all cases of combustion is proportional, not to the combustible, but to the oxygen absorbed. Oxygen gas, then, is composed of oxygen and caloric: and if this be the case with one gas, why not with all?

* Lavoisier,
p. i. ch. 9.

Caloric.

We may conclude, therefore, that the gases, as well as liquids and vapours, owe their form to the caloric which they contain. The only difference between them and vapours is, that the latter return to their liquid state by the mere action of cold; whereas most of the gases resist the lowest temperature which it has been possible to apply. It was natural to expect, that if caloric combined chemically with bodies, its affinity would be different for different substances, and that its affinity for some bodies would be so great that it would not leave them to combine with any other. It was natural to expect this, because it is the case with every other substance with which we are acquainted. The difference, then, between the gases and vapours is not surprising. The affinity of the former for caloric is not only much greater than that of the latter, but much greater than that of any other substances.

It is owing to this strong affinity between oxygen, hydrogen, and azot and caloric, that they cannot be obtained except in a gaseous form: and we shall describe several other substances afterwards exactly in the same circumstances. Had we any substance possessed of a greater affinity for caloric than they have, we should be able, by presenting it, to deprive them of their gaseous form. Doubtless there is a difference in the affinity between these bodies themselves and caloric; but as all of them are already saturated, this difference cannot be discovered. If we could obtain them uncombined with caloric, that is to say, in a concrete state, it would be easy to ascertain this point. Suppose, for instance, that hydrogen had the strongest affinity for caloric, and that we possessed it in a concrete state—it would be easy, by presenting it to the other gases, to deprive their bases of the caloric with which they are united, and thus to obtain them also uncombined with any other substance.

But though we are acquainted with no substance that has a greater affinity for caloric than the bases of the gases, there are many substances which have a greater affinity for these bases than caloric has. When any such substance is presented, the base combines with it, and the caloric is left at liberty. Thus, when phosphorus is presented to oxygen gas, the phosphorus and oxygen unite together, and the caloric flies off. We are now, therefore, able to answer one of the questions proposed at the end of the second chapter, Whence comes the caloric which appears during combustion? It is separated from the oxygen, which leaves it in order to enter into a new combination.

The caloric also, which sometimes appears when two bodies combine together, is set at liberty exactly in the same manner. When sulphuric acid and water, for instance, are mixed together, a very considerable heat is produced; a good deal of caloric, therefore, becomes sensible. In this case, the water combines with the acid, and at the same time lets go the caloric with which it was formerly combined, and becomes denser. In the same manner, to give another instance, when water is poured upon quicklime, a very great quantity of caloric becomes manifest. The water in this case combines with the quicklime, and assumes a concrete form, and of course lets go the caloric with which it was previously united.

10. It is no uncommon thing in nature to observe two bodies, after combining together, manifesting a much stronger affinity for a third body than either of them

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And to be
the cause of
their gase-
ous form.

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Why calo-
ric appears
during
combustion,

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And during
many chem-
ical combi-
nations.

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Why cer-
tain mix-
tures pro-
duce cold.

Caloric.

them had while separate. Thus, silver has no perceptible affinity for sulphuric acid, neither has oxygen; but unite them together, and they combine with that acid very readily. A great many instances of the same kind might be produced. Were there substances, then, which, after combining together, have a greater affinity for caloric than any of them had while separate, this ought not to surprize us, because the same phenomenon is often observed in other bodies. Now this is actually the case with regard to caloric. Mix together, for instance, common salt and snow, the mixture instantly becomes liquid, and so cold, that it sinks the thermometer down to zero. In this case, the snow and salt united have a much stronger affinity for caloric than either of them had while separate; they attract it therefore from other bodies with which they happen to be in contact, till they have obtained a dose sufficient for their saturation; and this saturation they manifest by becoming liquid. It is for this reason that all salts produce cold during their solution in water, when the freezing point of the solution formed is below that of water. All such solutions have a strong affinity for caloric; they therefore attract it till they are saturated, which appears by their becoming fluid. A number of experiments have been lately made in order to procure artificial cold by means of such combinations. The most complete set of experiments of that nature with which we are acquainted, is those of Mr Walker, published in the Philosophical Transactions for 1795. We shall present the result of his experiments in the following Table:

TABLE of Freezing Mixtures.

Mixtures.	Thermometer sinks.
Muriat of ammonia 5 parts. Nitre - - - 5 Water - - - 16	From 50° to 10°.
Muriat of ammonia 5 Nitre - - - 5 Sulphat of soda 8 Water - - - 16	From 50 to 4.
Nitrat of ammonia 1 Water - - - 1	From 50 to 4.
Nitrat of ammonia 1 Carbonat of soda 1 Water - - - 1	From 50 to 7.
Sulphat of soda 3 Diluted nitric acid 2	From 50 to 3.
Sulphat of soda 6 Muriat of ammonia 4 Nitre - - - 2 Diluted nitric acid 4	From 50 to 10.
Sulphat of soda 6 Nitrat of ammonia 5 Diluted nitric acid 4	From 50 to 14.
Phosphat of soda 9 Diluted nitric acid 4	From 50 to 12.

Caloric.

Mixtures.	Thermometer sinks.
Phosphat of soda 9 parts. Nitrat of ammonia 6 Diluted nitric acid 4	From 50° to 21°.
Sulphat of soda 8 Muriatic acid - 5	From 50 to 0.
Sulphat of soda 5 Diluted sulphuric acid 4	From 50 to 3.
Snow - - - 1 Common salt - 1	From 32 to 0.
Snow or pounded ice 2 Common salt - 1	From 0 to -5.
Snow or pounded ice 1 Common salt - 5 Muriat of ammonia and Nitre - - - 5	From -5 to -18.
Snow or pounded ice 12 Common salt - 5 Nitrat of ammonia 5	From -18 to -25.
Snow and diluted nitric acid	From 0 to -46.
Snow - - - 2 Diluted sulphuric acid 1 Diluted nitric acid 1	From -10 to -56.
Snow - - - 1 Diluted sulphuric acid 1	From 20 to -60.

In order to produce these effects, the salts employed must be fresh crystallized, and newly reduced to a very fine powder. The vessels in which the freezing mixture is made should be very thin, and just large enough to hold it, and the materials should be mixed together as quickly as possible. The materials to be employed in order to produce great cold ought to be first reduced to the temperature marked in the table, by placing them in some of the other freezing mixtures; and then they are to be mixed together in a similar freezing mixture. If, for instance, we wish to produce a cold = -46, the snow and diluted nitric acid ought to be cooled down to 0, by putting the vessel which contains each of them into the 12th freezing mixture in the above table, before they are mixed together. If a still greater cold is required, the materials to produce it are to be brought to the proper temperature by being previously placed in the second freezing mixture. This process is to be continued till the required degree of cold has been procured*.

11. From the facts already known, we may conclude, ^{* Walker, Phil. Trans. 1795.} that the particles of caloric have two properties, that of repelling each other, and of attracting and being attracted by other substances. ²⁸³ As there is no body in which caloric nature which does not contain caloric, we may safely conclude, that there is no body in nature which has not an affinity for it. When it unites with bodies, though the repulsion of its particles may be overcome by their attraction for the particles of the body, and by the attraction

^{Caloric.} traction of these particles for each other—we cannot suppose it annihilated: It must therefore be the more powerful the greater the quantity of caloric combined in any body is. Probably, then, there is most caloric combined with gases, less with fluids, and least with solids. It does not follow, however, from this, that the quantity of caloric combined with any body is proportional to the distance between its particles, because that may depend on other causes. Thus, though hydrogen gas is much rarer than oxygen gas, it does not follow that hydrogen is combined with more caloric than oxygen, because the rarity may be owing to the smaller cohesive force of the particles of hydrogen allowing a smaller quantity of caloric to produce a greater effect.

²⁸⁴
Caloric
may be
added in-
definitely
to bodies,

If caloric unites *only* chemically with bodies, there ought to be a certain point of saturation between it and the substances with which it combines, because this takes place in all other chemical combinations. Oxygen gas, for instance, consists of a certain quantity of oxygen united with caloric. Now if this gas be a *chemical* compound, the two ingredients ought to saturate each other in such a manner, that no more of either could be admitted. But it cannot be denied, that more caloric can still be added to oxygen gas, for its temperature may be raised at pleasure as high as we think proper. This, at first sight, seems to be an insuperable objection to the theory, that caloric only combines chemically with bodies. It ought to be remembered, however, that caloric is not singular in this respect. There are other bodies in nature, and bodies too which certainly combine with other substances only by affinity, which exhibit the very same phenomenon. Water is capable of combining with sulphuric acid and many other salts almost in any proportion, at least no limits have hitherto been observed. Oxygen, too, combines with almost every body in various proportions: We have seen, that with almost every metal it forms at least two different oxides. Why then may not caloric be capable of uniting in the same manner? Allowing, therefore, that it were impossible to explain why bodies are capable of combining with caloric after saturation, this could be no objection to the theory that it only unites chemically with bodies, because the same phenomenon is exhibited by other bodies which it cannot be doubted combine only by means of affinity.

²⁸⁵
And why.

The manner in which these other combinations are formed has been already hinted, and shall be considered more fully afterwards; at present we shall only attempt to explain the action of caloric. Let us suppose, then, that caloric is presented to oxygen; that they combine together in a certain proportion, and saturate each other. The product of this combination is oxygen gas; a substance possessed of properties very different from those of caloric or oxygen in a concrete state; it is incapable of being decomposed by any merely mechanical method, and exhibits all the appearances of a simple substance. Let us therefore consider this compound for a moment as a simple substance. May it not still have an affinity for caloric? and will it not, in that case, unite with it? Oxygen gas and caloric have an affinity for each other; accordingly when presented to one another they combine in a certain proportion, and form a new compound, differing from oxygen gas, properly so called, in elasticity, specific gravity, and several other particulars. The affinity, however, between oxygen gas and caloric is much

feebler than that between oxygen and caloric; for the new compound is easily broken, and the caloric absorbed by many other substances. We can even conceive this new compound still to have an affinity for caloric, to unite with it, and to form another compound, the affinity between the ingredients of which is still feebler. And in this manner may the indefinite increase of temperature be accounted for.

^{Caloric.}

Substances may be conceived to be conductors of caloric inversely as their affinity for it. Good conductors may have very little affinity for caloric; and for that reason it may be easily forced through them by the repulsion of its own particles. But those substances which have a great affinity for caloric, combine with it the moment it is presented to them; and consequently it cannot pass through them. Thus, when it is presented to ice, the affinity between the two substances is so great, that the caloric unites with the very first particles of ice which it meets with. The particles behind these cannot receive any caloric, except by attracting it from the particles with which it has already combined. But the affinity of one particle of ice for caloric cannot be greater than that of another particle of ice: and the union of two bodies cannot be broken by a force not greater than that which unites them; therefore the caloric cannot pass from one particle to another. Consequently, supposing all the particles to keep their places, no new caloric could enter. Just as when a piece of marble is put into sulphuric acid, the crust of sulphat of lime which very soon covers it prevents the acid from getting to the particles of marble within. But as soon as a particle of ice unites with caloric, water, the new compound, leaves its station, and allows the caloric a passage to the other particles.

²⁸⁶
Cause of
the diffe-
rent con-
ducting
powers of
different
bodies.

In the same manner, when caloric is presented to water, it combines with the outermost stratum of particles, and forms with them a compound which cannot be decomposed by the other particles of the water, because their affinity for caloric is no greater than that of the particles already united with it. No more caloric, then, could gain admission, were it not that (the specific gravity of the new compound being inferior to that of the uncombined water) it immediately changes its place, and allows another stratum of particles to occupy its room. These unite with caloric, and are displaced in their turn. And in this manner the process goes on, till all the particles have combined with caloric; or, which is the same thing, till the whole of the water is heated.

But supposing the first stratum of particles to remain in their place after their union with caloric, we can conceive an affinity still to subsist between the new compound, thus formed, and caloric. In that case the new compound, which we shall call A, would combine with an additional dose of caloric, and form a second compound B, differing in several respects from the first. We can conceive also the affinity between the first compound A and caloric to be inferior to that between water and caloric. In that case, the second stratum of particles of water would separate the additional dose with which the first stratum had united. In this manner would two stratums of particles combine with caloric. The first stratum of particles would combine with another dose of caloric, and form a second compound B as before. But this compound could not now be decomposed by the second stratum of particles, because

²⁸⁷
How heat
passes thro'
solids.

^{Caloric.} because they had already united with a dose of caloric ; and therefore their affinity for a new dose could be no greater than that of the first stratum of particles. The process of heating could go on no farther. But we can conceive the second compound B, into which the first stratum has entered, still to have an affinity for caloric, to combine with a dose of it, and to form with it a third compound C. We can conceive, at the same time, the affinity between the second compound B and caloric to be less than that between the first compound A and caloric. In that case, the second stratum of particles would take this last dose from the first stratum, and form with it a second compound B. The third stratum of particles, which is still uncombined with caloric, would now attract this new dose from the second stratum, and combine with it. And, supposing the caloric still flowing towards the water, the first stratum would again form the third compound C, by uniting with a fresh dose : this new dose would be again attracted by the second stratum, and the first stratum would again form the third compound C, by uniting with another dose of caloric. Thus three stratums of particles would be combined with caloric ; the first stratum would contain three doses, the second stratum two, and the third one. The process of heating would again stop ; because now the affinity of the second stratum is no greater than that of the first, nor the affinity of the third stratum greater than that of the second, nor that of the fourth than that of the third. But we can conceive an affinity still to subsist between caloric and the third compound C, into which the first stratum has entered, and this affinity, at the same time weaker than that between the second compound B and caloric. In that case they would combine and form a fourth compound D. This new dose would be attracted by the second stratum of particles, which would combine with it and form the third compound C ; the third stratum would attract it from the second, and form with it the second compound B ; and the fourth stratum would attract it from the third, and enter into the first compound A. The first stratum would again enter into the fourth compound D ; which would be again decomposed by the second stratum ; and the compound formed by the second stratum, by the third stratum. The fourth compound D would be again formed by the first stratum, and again decomposed by the second stratum. It would be formed a third time, and could not now be decomposed. Four stratums of particles would now have combined with caloric : the first stratum with four doses ; the second, with three doses ; the third, with two ; and the fourth, with one. We can conceive this process to go on exactly in the same manner, till all the particles of water have combined with a dose of caloric. In that case, the quantity of caloric combined with every stratum of particles would form a regular decreasing series from that part of the water at which the caloric enters to that part which is farthest distant from it. The process of heating would go on very slowly ; and the heat of that part of the water which is farthest distant from the source of caloric could never be nearly equal to that of the part which is nearest to that source. This seems in fact to be the manner in which all those solids are heated which are bad conductors of caloric : in all probability it is the way in which all solids are heated.

That caloric combines with bodies merely by means of affinity, seems at first sight contrary to fact ; for there is no substance whatever which may not be cooled indefinitely merely by surrounding it with other bodies which are colder than itself. Place a piece of hot iron, for instance, in cold water, it is very soon cooled down to the temperature of that liquid. This seems plain enough ; the attraction of water for caloric is greater than that of iron : but reverse the experiment ; put hot water within cold iron, and the water is cooled in its turn down to the temperature of the iron : so that the iron also has a greater affinity for caloric, as well as the water ; which is absurd.

But it ought to be remembered, that caloric not only possesses affinity, but that it has another property also, of which every other species of matter, except perhaps light, seems to be destitute, a repulsion between its own particles. It is necessary for all organised bodies, and probably for all bodies, that they should possess a certain quantity of caloric ; and on this account the greatest care has been taken to secure its equal distribution. This seems to be one use at least of its repulsive power ; a power which is never destroyed, however closely caloric is united with other bodies. We have shewn already, that this power is increased by diminishing the quantity of surrounding caloric ; and when thus increased to a certain degree, it may at last equal, and even exceed, the affinity between the caloric and the bodies to which it is united ; and in that case part of the caloric would necessarily fly off. It seems to be in this manner that bodies reciprocally cool each other, and that they have always a tendency to an equilibrium of temperature. Thus steam by cold is converted into water, and water into ice. And the affinity between bodies and that caloric which is employed in regulating the temperature seems to be so weak, that the repulsion between the particles of caloric easily overcomes it, and restores the equilibrium. But the affinity between some substances and caloric is so great, that no diminution of temperature has been found sufficient to overcome it. This is the case, as we have already seen, with oxygen gas.

The specific caloric of bodies seems to depend on two things ; their affinity for caloric, and the distance between their particles. For what is temperature but the disposition of a body to part with caloric ? The more caloric a body is disposed to part with, we call its temperature the higher ; the less it parts with when a colder body is applied, its temperature is said to be the lower. If oxygen gas parts with no caloric to a thermometer which stands at -10° , we say its temperature is -10 ; yet we know that even then it contains, in all probability, much more caloric than the mercury in the thermometer does. Now the stronger the affinity between any substance and caloric, the greater quantity of caloric will be required before the repulsion between its particles is sufficient to overcome this attraction ; consequently the more caloric is necessary to raise it a given number of degrees. And the farther distant the particles of bodies are, the farther from one another must the particles of caloric be to which they are united ; and consequently the weaker must be the repulsion between them.

We cannot deny how new this theory of the action of caloric will appear to those who have been accustomed

Caloric.

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Bodies cool each other reciprocally.

289

And why.

290

Cause of the difference in the specific caloric of bodies.

Caloric.

Caloric.

ed to look upon Dr Crawford's opinions on this subject as fully proved; nor do we pretend that it can be reconciled with these opinions. But this, we hope, is no proof of its falsehood. We think it can be fairly deduced from Dr Black's doctrine of latent heat: we know, too, that Bergman believed caloric capable of combining chemically with bodies: and Morveau has not only embraced the same opinion, but seems to affirm, that all the combinations into which caloric enters are chemical*. And were this question to be decided by authority, we appeal to all the world, whether other three men could be produced to whose decisions one would more willingly submit (1). We do not, however, mean to rest its evidence on authority; let it be compared with facts, and put to the test of experiment; and by its correspondence with these let it stand or fall.

* Encyc.
Method.
Chim. art.
Affinité.

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Caloric hastens solution, and increases the solvent power of water.

12. Caloric both hastens the solution of salts in water, and increases the solvent power of the water; for water dissolves a much greater quantity of almost every salt when hot than when cold. The reason that caloric produces these effects is obvious from those properties of it which have been described. It hastens solution by putting the particles of the fluid in motion, and thus bringing all of them in their turn into contact with the salt: for only those particles can act as solvents which are in contact with the salt. It increases the solvent power of the fluid by combining with it, and forming a compound which has a greater affinity for the salt, and which therefore dissolves more of it than the fluid alone would have done. This new compound is destroyed by cooling; and then the additional dose of the salt which had been dissolved is precipitated.

13. We should come now to the consideration of the two remaining questions proposed at the end of the second chapter, Why do bodies combine with oxygen at one temperature and not at another? And why is caloric necessary to produce this union? But as the difficulty of these questions is not inferior to their importance, we shall delay any attempt to answer them till we come to treat of affinity.

292
Methods of obtaining caloric.

14. It now only remains to consider the methods by which caloric may be obtained in a sensible state. These methods may be reduced to four; combustion, percussion, friction, and light: the last of which shall be considered afterwards.

293
Combustion explained.

We have seen already, that the combustion of *simple combustibles and metals* is merely their combination with oxygen, during which the oxygen parts with the caloric with which it was formerly united. Now the very same thing takes place in other combustions. The combustible unites with oxygen, which at the same time gives out its caloric. The change then which the combustible body suffers is not owing to the action of caloric on it, but to its combining with oxygen. The very same change can be brought about without any of the usual phenomena which attend combustion, simply by presenting the oxygen combined with some other body instead of caloric. Nitric acid, for instance, is a body which contains in it a good deal of oxygen: If phosphorus be mixed with this acid, it attracts part

of the oxygen, and, without any of the usual phenomena which attend combustion, is converted into phosphoric acid. Strictly speaking, then, combustion is nothing else but the combination of oxygen with the burning body, and the term might therefore be used in every case where such an union takes place; and in this sense indeed it is now employed by several writers. But the term *combustion* is in common language confined to those cases where the oxygen was previously combined with caloric, and where a quantity of heat and light become sensible; and perhaps it would be better, in order to prevent ambiguity, never to employ it in any other sense. We are not yet absolutely certain that caloric and light may not become sensible in other combinations besides those into which oxygen enters. There are other substances besides oxygen capable of combining with caloric; for instance, hydrogen and azot: and unless their affinity for caloric be greater than for any other substance, they may be capable of combining with other substances, and separating from caloric, at least the impossibility of this has never yet been demonstrated. It is improper, therefore, to appropriate the word *combustion* to the combinations of oxygen, till it can be shewn that the phenomena usually denoted by that name are never owing to any other cause. There is even one case in which these phenomena present themselves, in which we are next to certain that oxygen has no share. There is an affinity between sulphur and iron, and a high temperature promotes their union. When these substances are mixed together, and heated till they just begin to appear red hot, they combine together, and at the same time, as the Dutch chemists first observed, a good deal of caloric and light is evolved. The very same phenomena appear in a vacuum, or in any kind of air whatever. The explanation of them is very simple and obvious. The sulphur or the iron, or perhaps both, had previously been combined with a quantity of caloric; and when they united together, this caloric of course separated from them.

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Whether it ever takes place when oxygen is not present.

The theory of combustion adopted by the earlier chemists was very different from the preceding. Stahl, as has been already explained, considered combustion in every instance as owing to the separation of phlogiston; and this opinion soon became universal. He considered phlogiston as the same thing with the element of fire; which was capable both of becoming fixed in bodies, and of existing in a state of liberty. Two of its properties in this last state were heat and light. The heat and the light, then, which became sensible during combustion, were nothing else, according to Stahl, but two properties of phlogiston or the element of fire. Macquer, to whose illustrious labours several of the most important branches of chemistry owe their existence, we believe, the first person who perceived this striking defect in this theory of Stahl. Sir Isaac Newton had proved that light is a body; it was absurd, therefore, to make it a mere property of phlogiston or the element of fire. Macquer accordingly considered phlogiston as nothing else but light fixed in bodies. This opinion was embraced by a great number of the most

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Stahl's theory of combustion by the extrication of phlogiston.

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Improved by Macquer.

(1) The same opinion has been embraced by Seguin, Pictet, Gadolin, and several other philosophers. We did not mention them, because the theory given above differs in a few particulars from theirs. But we have derived much instruction from their ingenious writings; and many of the facts which we have given were obtained from them.

^{Caloric.} distinguished chemists; and many ingenious arguments were brought forward to prove its truth. But if phlogiston be only light fixed in bodies, whence comes the heat that manifests itself during combustion? Is this heat merely a property of light? Dr Black proved that heat is capable of combining with, or becoming fixed in bodies which are not combustible, as in ice and water; and concluded of course, that it is not a property but a body. From that time heat or caloric was considered by the greatest number of chemists as a distinct substance from phlogiston.

²⁹⁷ Priestley, Soon after this, a phenomenon, which had been observed from the earliest ages, and which probably, for that very reason, had been neglected, began to be attended to; that combustibles would not burn except in contact with air. Dr Priestley observed, that the air in which combustibles had been suffered to burn till they were extinguished, had undergone a very remarkable change; for no combustible would afterwards burn in it, and no animal could breathe it without suffocation (κ). He concluded, as Dr Rutherford had done before him, that this change was owing to phlogiston; that the air had combined with that substance; and that air was necessary to combustion, by attracting the phlogiston, for which it had a strong affinity. If so, phlogiston could not be light any more than caloric; for if it separated from the combustible merely by combining with air, it could not surely display itself in the form of light. The question then re-

²⁹⁸ And Crawford, Crawford, of whose ingenious experiments on the specific caloric of bodies we have already given an account, without attempting to answer this question, made a considerable improvement in the theory of combustion, by supposing that the phlogiston of the combustible combined with the air, and at the same time separated the caloric and light with which that fluid had been previously united. The heat and the light, then, which appeared during combustion, existed previously in the air. This theory was very different from Stahl's, and certainly a great deal more satisfactory. But still the question, What is phlogiston? remained to be answered. ²⁹⁹ Kirwan's theory of phlogiston, Mr Kirwan, who had already raised himself to the first rank among chemical philosophers by many

important discoveries, and many ingenious investigations of some of the most difficult parts of chemistry, attempted to answer this question, and to prove that phlogiston was the same with hydrogen*. The subject was now brought to a state capable of the most complete decision. Does hydrogen actually exist in all combustible substances? and is it separated from them during every combustion? The French chemists who answered his treatise, shewed that this is by no means the case; and that therefore there was no proof whatever of the identity of phlogiston and hydrogen. And Mr Kirwan in consequence, with that candour which distinguishes superior minds, gave up his opinion as untenable.

Mr Lavoisier had already put the question, What proof is there of the existence of phlogiston at all? There is only this single proof, that substances after combustion are different from what they formerly were. That this difference takes place is certainly true; but it is owing, not to the separation of any substance, but to the combination of one. It follows, therefore, that there is no proof whatever of the existence of any such substance as *phlogiston* in nature; and of course we must conclude that no such substance exists (L).

³⁰¹ Existence of phlogiston disproved. 15. It is well known that heat is produced by the percussion of hard bodies against each other. When a piece of iron is smartly and quickly struck with a hammer, it becomes red hot; and the production of sparks by the collision of flint and steel is too familiar a fact to require being mentioned. No heat, however, has ever been observed to follow the percussion of liquids, nor of soft bodies which easily yield to the stroke.

It has long been known, that hammering increases the density of metals. The specific gravity of iron before hammering is 7,788; after being hammered, 7,840: that of platinum before hammering is 19,50; after it, 23,00. Now condensation diminishes the specific caloric of bodies. After one of the clay pieces used in Wedgewood's thermometer has been heated to 120°, it is reduced to one half of its former bulk, though it has lost only two grains of its weight, and its specific caloric is at the same time diminished one third †. But we cannot conceive the specific caloric of a body to be diminished without its giving out at the same time a quantity

³⁰² Production of caloric by percussion,

³⁰³ Owing partly to condensation, * T. Wedgewood, Phil. Transf. 1792.

(κ) These very observations had been made almost a century before by Mayow; but chemistry was then in its infancy; little attention was paid to them, and they had been forgotten.

(L) Mr Lavoisier was therefore the author of what is called the *antiphlogistic theory* in chemistry, or the theory which accounts for the phenomena of chemistry without the assistance of phlogiston. It has been so called in opposition to the theory of Stahl, which explained every thing by means of *phlogiston*, and which is therefore called the *phlogistic theory*.

Some chemists have affected to omit Lavoisier's name altogether, when they spoke of the antiphlogistic theory. According to them, that theory was founded upon the experiments and discoveries of other chemists, and Lavoisier had no other merit but that of bringing it into public notice.

That Mr Lavoisier, virtually at least, claimed several of the discoveries of others, we are sorry to be under the necessity of acknowledging; and that many of the experiments, brought forward to disprove the existence of phlogiston, were first made by others, is known to all the world: but it is equally evident, that the first person who actually formed the theory was Lavoisier; and surely the merit lies in that. It is not those who collect the stones, and the timber, and the mortar, but he who lays the plan, and shews how to put the materials together, that is in reality the builder of the house. Who did not know, as well as Newton, that a stone fell to the ground, and that the planets revolved round the sun? and yet, who but Newton could have formed the theory of gravitation? We would not be understood to detract any thing from the merit of the other illustrious philosophers who have adorned the present age, many of whom are at least equal, and some of them superior to Lavoisier: But we are afraid that envy, or some worse motive, guided the pen of one at least of the most active and virulent antagonists of that illustrious and unfortunate philosopher. It must not, however, be concealed, that his theory of combustion is incomplete. See COMBUSTION in this Supplement.

Caloric. quantity of caloric; and we know for certain that caloric is evolved during condensation. A thermometer placed within a condenser rises several degrees every time air is thrown in *. We can even see a reason for this. When the particles of a body are forced nearer each other, the repulsive power of the caloric combined with them is increased, and consequently a part of it will be apt to fly off. Now, after a bar of iron has been heated by the hammer, it is much harder and brittle than before. It must then have become denser, and consequently must have parted with caloric. It is an additional confirmation of this, that the same bar cannot be heated a second time by percussion until it has been exposed for some time to a red heat. It is too brittle, and flies to pieces under the hammer. Now brittleness seems in most cases owing to the absence of the usual quantity of caloric. Glass *unannealed*, or, which is the same thing, that has been cooled very quickly, is always extremely brittle. When glass is in a state of fusion, there is a vast quantity of caloric accumulated in it, the repulsion between the particles of which must of course be very great; so great indeed, that they would be disposed to fly off in every direction with inconceivable velocity, were they not confined by an unusually great quantity of caloric in the surrounding bodies: consequently if this surrounding caloric be removed, the caloric of the glass flies off at once, and more caloric will leave the glass than otherwise would leave it, because the velocity of the particles must be greatly increased. Probably then the brittleness of glass is owing to the deficiency of caloric; and we can scarcely doubt that the brittleness of iron is owing to the same cause, if we recollect that it is removed by the application of new caloric. Part therefore of the caloric which appears in consequence of percussion seems to proceed from the body struck; and this is doubtless the reason why those bodies, the density of which is not increased by percussion, as liquids and soft substances, are not heated at all.

³⁰⁴ And partly to combustion. We say *part* of the caloric, because, often at least, part of it is probably owing to another cause. By condensation, as much caloric is evolved as is sufficient to raise the temperature of some of the particles of the body high enough to enable it to combine with the oxygen of the atmosphere. The combination actually takes place, and a great quantity of additional caloric is separated by the decomposition of the gas. That this happens during the collision of flint and steel cannot be doubted; for the sparks produced are merely small pieces of iron heated red hot by uniting with oxygen during their passage through the air, as any one may

convince himself by actually examining them. Mr Lane has shewn that iron produces no sparks in the vacuum of an air-pump; but Mr Kirwan has observed that they are produced under common spring water; and we know that iron at a certain temperature is capable of decomposing water.

When quartz, rock-crystal (M), or other very hard stones, are struck against one another they emit sparks. If they be often made to emit sparks above a sheet of white paper, there are found upon it a number of small black bodies, not very unlike the eggs of flies. These bodies are hard but friable, and when rubbed on the paper leave a black stain. When viewed with a microscope, they seem to have been melted. Muriatic acid changes their colour to a green, as it does that of lavas *. These substances evidently produced the sparks by being heated red hot. Lamanon (N) supposes that they are particles of quartz combined with oxygen. Were that the case, the phenomenon would be precisely similar to that which is produced by the collision of flint and steel. That they are particles of quartz cannot be doubted; but to suppose them combined with oxygen is contrary to all experience: for these stones never shew any disposition to combine with oxygen even when exposed to the most violent heat. La Metherie made experiments on purpose to see whether Lamanon's opinion was well founded; but they all turned out unfavourable to it. And Mongé ascertained, that the particles described by Lamanon were pure crystal unaltered, with a quantity of black powder adhering to them. He concludes accordingly, that these fragments had been raised to so high a temperature during their passage through the air, that they set fire to all the minute bodies that came in their way †. We must therefore either suppose that all the caloric was produced by mere condensation, which is not probable, or acknowledge that we cannot explain the phenomenon.

16. Caloric is not only produced by percussion, but also by friction. Fires are often kindled by rubbing pieces of dry wood smartly against one another. It is well known that heavy loaded carts sometimes take fire by the friction between the axle-tree and the wheel. Now in what manner is the caloric evolved or accumulated by friction? Not by increasing the density of the bodies rubbed against each other, as happens in cases of percussion; for heat is produced by rubbing soft bodies against each other, the density of which therefore cannot be increased by that means, as any one may convince himself by rubbing his hand smartly against his coat. It is true, indeed, that heat is not produced by the friction of liquids, but then they are too yielding to

(M) These stones are composed of almost pure silica.

(N) This ingenious and unfortunate young man, to whom we are indebted for these facts, fell a victim to his ardour for knowledge. He accompanied La Perouse in his last voyage, and was murdered with the most savage cruelty, together with La Langle and several others, by the natives of the island of Maoua. When a man of genius, anxious to acquire honest fame, and a man too so nobly disinterested as Lamanon, thus falls prematurely before he has attained the object of his wishes,

“Cut off from nature's and from glory's course!
“Which never mortal was so fond to run,”

who can withhold the tribute of regret and admiration, when they

— “Conjecture what he might have proved,
“And think life only wanting to his fame.”

Caloric.
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 Nor to decrease of specific caloric.
 * Nicholson's Journ. ii. 106.

to be subjected to strong friction. It is not owing to the specific caloric of the rubbed bodies decreasing; for Count Rumford found that there was no sensible decrease *, nor, if there were a decrease, would it be sufficient to account for the vast quantity of heat which is sometimes produced by friction.

Count Rumford took a cannon cast solid and rough as it came from the foundery; he caused its extremity to be cut off, and formed, in that part, a solid cylinder attached to the cannon $7\frac{1}{4}$ inches in diameter and $9\frac{3}{8}$ inches long. It remained joined to the rest of the metal by a small cylindrical neck. In this cylinder a hole was bored $3\frac{7}{8}$ inches in diameter and 7,2 inches in length. Into this hole was put a blunt steel borer, which by means of horses was made to rub against its bottom; at the same time a small hole was made in the cylinder perpendicular to the bore, and ending in the solid part a little beyond the end of the bore. This was for introducing a thermometer to measure the heat of the cylinder. The cylinder was wrapt round with flannel to keep in the heat. The borer pressed against the bottom of the hole with a force equal to about 10,000 lb. avoirdupois, and the cylinder was turned round at the rate of 32 times in a minute. At the beginning of the experiment the temperature of the cylinder was 60° ; at the end of 30 minutes, when it had made 960 revolutions, its temperature was 130° . The quantity of metallic dust or scales produced by this friction amounted to 837 grains. Now, if we were to suppose that all the caloric was evolved from these scales, as they amounted to just $\frac{1}{8}\frac{1}{8}$ part of the cylinder, they must have given out 948° to raise the cylinder 1° , and consequently 66360° to raise it 70° or to 130° , which is certainly incredible †.

Neither is the caloric evolved during friction owing to the combination of oxygen with the bodies themselves or any part of them. By means of a piece of clock-work, Mr Piñet made small cups (fixed on the axis of one of the wheels) to move round with considerable rapidity, and he made various substances rub against the outsides of these cups, while the bulb of a very delicate thermometer placed within them marked the heat produced. The whole machine was of a size sufficiently small to be introduced into the receiver of an air-pump. By means of this machine a piece of adamant spar was made to rub against a steel cup in air: sparks were produced in great abundance during the whole time, but the thermometer did not rise. The same experiment was repeated in the exhausted receiver of an air-pump (the manometer standing at four lines); no sparks were produced, but a kind of phosphoric light was visible in the dark. The thermometer did not rise. A piece of brass being made to rub in the same manner against a much smaller brass cup in air, the thermometer (which almost filled the cup) rose $0,3^\circ$, but did not begin to rise till the friction was over. This shews us that the motion produced in the air carried off the caloric as it was evolved. In the exhausted receiver it began to rise the moment the friction began, and rose in all $1,2^\circ$. When a bit of wood was made to rub against the brass cup in the air, the thermometer rose $0,7^\circ$, and on substituting also a wooden cup it rose $2,1^\circ$, and in the exhausted receiver $2,4^\circ$, and in air condensed to $1\frac{1}{2}$ atmospheres it rose $0,5^\circ$ *.

* Piñet sur le Feu, ch. 9. If these experiments be not thought conclusive, we have others to relate, which will not leave a doubt that

the heat produced by friction is not connected with the decomposition of oxygen gas. Count Rumford contrived, with his usual ingenuity, to enclose the cylinder above described in a wooden box filled with water, which effectually excluded all air, as the cylinder itself and the borer were surrounded with water, and at the same time did not impede the motion of the instrument. The quantity of water amounted to 18,77 lbs. avoirdupois, and at the beginning of the experiment was at the temperature of 60° . After the cylinder had revolved for an hour at the rate of 32 times in a minute, the temperature of the water was 107° ; in 30 minutes more it was 178° ; and in 2 hours and 30 minutes after the experiment began, the water *actually boiled*. According to the computation of Count Rumford, the caloric produced would have been sufficient to heat 26,58 lbs. avoirdupois of ice-cold water boiling hot; and it would have required 9 wax candles of a moderate size, burning with a clear flame all the time the experiment lasted, to have produced as much heat. In this experiment all access of water into the hole in the cylinder where the friction took place was prevented. But in another experiment, the result of which was precisely the same, the water was allowed free access *.

The caloric, then, which appears in consequence of friction, is neither produced by an increase of the density, nor by an alteration in the specific caloric of the substances exposed to friction, nor is it owing to the decomposition of the oxygen of the atmosphere.—Whence then is it derived? This question we are altogether unable to answer. We cannot, however, think that the conclusion which Count Rumford is disposed to draw from his experiments is warranted by the premises. He supposes, that because we cannot explain the manner that caloric is accumulated by friction, there is no such substance as caloric at all, but that it is merely a *peculiar kind of motion*. We would beg leave to ask, how the facts mentioned in the former part of this chapter, many of which were furnished by this ingenious philosopher himself, and all of which combine to render the existence of caloric as a substance probable, can be destroyed and set aside, merely because there are other phenomena in nature connected with caloric which cannot be accounted for? Were it possible to prove that the accumulation of caloric by friction is *incompatible* with its being a substance, in that case Count Rumford's conclusion would be a fair one; but this surely has not been done. We are certainly not yet sufficiently acquainted with the laws of the motion of caloric (allowing it to be a substance) to be able to affirm with certainty that friction could not cause it to accumulate in the bodies rubbed. This we know at least to be the case with electricity. Nobody has been hitherto able to demonstrate, in what manner it is accumulated by friction; and yet this has not been thought a sufficient reason to deny its existence.

Indeed there seems to be a very close analogy between caloric and electric matter. Both of them tend to diffuse themselves equally, both of them dilate bodies, both of them fuse metals, and both of them kindle combustible substances. Mr Achard has proved, that electricity can be substituted for caloric even in those cases where its agency seems peculiarly necessary; for he found that, by constantly supplying a certain quantity of the electric fluid, eggs could be hatched just as when they are kept

Caloric.

* Nicholson, *ibid.*311
And consequently at present inexplicable.312
This no proof that caloric is not a body.313
Analogy between caloric and electricity.

Caloric.

kept at the temperature of 103° . An accident indeed prevented the chickens from actually coming out; but they were formed and living, and within two days of bursting their shell. Electricity has also a great deal of influence on the heating and cooling of bodies. Mr Pictet exhausted a glass globe, the capacity of which was 1200,199 cubic inches, till the manometer within it stood at 1,75 lines. In the middle of this globe was suspended a thermometer which hung from the top of a glass rod fixed at the bottom of the globe, and going almost to its top. Opposite to the bulb of this thermometer two lighted candles were placed, the rays of which, by means of two concave mirrors, were concentrated on the bulb. The candles and the globe were placed on the same board, which was supported by a non-conductor of electricity. Two feet and a half from the globe there was an electrifying machine, which communicated with a brass ring at the mouth of the globe by means of a metallic conductor. This machine was kept working during the whole time of the experiment; and consequently a quantity of electric matter was constantly passing into the globe, which formed an atmosphere not only within it, but at some distance round, as was evident from the imperfect manner in which the candles burned. When the experiment began the thermometer stood at $49,8^{\circ}$. It rose to $72,2^{\circ}$ in $732''$. The same experiment was repeated, but no electric matter thrown in; the thermometer rose from $49,8^{\circ}$ to $70,2^{\circ}$ in $1050''$; so that the electricity hastened the heating almost a third. In the first experiment the thermometer rose only to $71,3^{\circ}$, but in the second it rose to 77° . This difference was doubtless owing to the candles burning better in the second than the first experiment; for in other two experiments made exactly in the same manner, the maximum was equal both when there was and was not electric matter present. These experiments were repeated with this difference, that the candles were now insulated, by placing their candlesticks in dishes of varnished glass. The thermometer rose in the electrical vacuum from $52,2^{\circ}$ to $74,7^{\circ}$ in $1050''$; in the simple vacuum in $965''$. In the electrical vacuum the thermometer rose to 77° ; in the simple vacuum to 86° . It follows from these experiments, that when the globe and the candles communicated with each other, electricity hastened the heating of the thermometer; but that when they were insulated separately, it retarded it*. One would be apt to suspect the agency of electricity in the following experiment of Mr Pictet: Into one of the brass cups formerly described, a small quantity of cotton was put to prevent the bulb of the thermometer from being broken. As the cup turned round, two or three fibres of the cotton rubbed against the bulb, and without any other friction the thermometer rose five or six degrees. A greater quantity of cotton being made to rub against the bulb, the thermometer rose 15 degrees †.

We do not mean to draw any other conclusion from these facts, than that electricity is very often concerned in the heating of bodies, and that probably some such agent is employed in accumulating the heat produced by friction. Supposing that electricity is actually a sub-

stance, and taking it for granted that it is different from caloric, does it not in all probability contain caloric as well as all other bodies? Has it not a tendency to accumulate in all bodies on friction, whether conductors or non-conductors? May it not then be accumulated in those bodies which are rubbed against one another? or, if they are good conductors, may it not pass through them during the friction in great quantities? May it not part with some of its caloric to these bodies, either on account of their greater affinity or some other cause? and may not this be the source of the caloric which appears during friction?

CHAP. VI. Of LIGHT.

By means of *light* bodies are rendered visible. Light has been considered as a substance composed of small particles moving in straight lines from luminous bodies with inconceivable rapidity. The discoveries of Newton established this opinion on the firm basis of mathematical demonstration; and since his time it has been generally embraced. Huyghens, indeed, and Euler, advanced another (o). They considered light as a subtle fluid, filling all space, which rendered bodies visible by its undulations. But they supported their hypothesis rather by starting objections to the theory of Newton, than by bringing forward direct proofs. Their objections, even if valid, instead of establishing their own opinions, would prove only that the phenomena of light are not completely understood; a truth which no man will refuse to acknowledge, whatever side of the question he adopts. Newton and his disciples, on the contrary, have shewn that the known phenomena of light are *inconsistent* with the undulations of a fluid, and have brought forward a great number of direct arguments, which it has been impossible to answer, in support of their theory. It can hardly be doubted, therefore, that the Newtonian theory of light is the true one.

Dr Bradley, who, by a number of very accurate experiments, and a process of reasoning peculiarly ingenious, discovered the aberration of light of the fixed stars, has shewn from it that the velocity of light is to that of the earth in its orbit as 10313 to 1. Light therefore moves at the rate of 195218 miles in a second.

Light, by means of a prism, may be separated into seven rays, differing from each other in colour; red, orange, yellow, green, blue, indigo, violet. None of these are capable of farther decomposition. Marat, indeed, pretended that he had reduced them to three; but his experiments are now known to have been merely philosophical frauds.

When light passes obliquely into a denser medium, it is refracted towards the perpendicular; when into a rarer, from the perpendicular. Sir Isaac Newton discovered that the rays differed in their refrangibility in the order in which they have been named, the red being the least, the violet the most refrangible. Mr Blair has observed, that the ratios of the refrangibility of the different rays, though not their order, vary somewhat in different mediums*.

When light passes within a certain distance of a body, parallel

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iii.

(o) Dr Franklin did the same, without taking any notice of these philosophers, of whose opinions perhaps he was ignorant. See *Transf. Philad.* III. 5.

Light.

315

Newtonian theory of light.

316

Velocity of light.

317

Divisible into seven rays.

318

Differing in refrangibility.

* Edinburg's Phil. Transf.

iii.

* Pictet sur le Feu. ch. 6.

† Ibid. ch. 9.

314 Electricity may be an agent in the heating of bodies by friction.

Light.
³¹⁹
 Inflection,
 deflection,

parallel to which it is moving, it is bent *towards* it; when it passes at a greater distance, it is bent *from* it. The first of these properties is called *inflection*, the second *deflection*. Now the rays differ in these properties in the order in which they were named; the red being *most*, the violet *least*, inflexible and deflexible. This was suspected by David Rittenhouse *, but was first demonstrated by the ingenious experiments of Mr Brougham †.

* *Transf. Philad. ii.*
 † *Phil. Transf.* 1796.
³²⁰
 And reflex-
 ity.

When light falls upon a visible body, some of it is reflected back; and the more polished or the whiter any surface is, the more light it reflects. The rays of light differ also in reflexivity, the red being the most, the violet the least reflexible. This discovery we owe to the same ingenious gentleman †.

‡ *Phil. Transf.* 1796.

These properties of light constitute the subject of OPTICS; to which we refer those who wish to see them investigated. We mention them here because they prove that light is acted on by other bodies, that it is subjected to the laws of attraction, and consequently that it possesses *gravity*.

2. The particles of light seem also, like those of caloric, to possess the property of repelling one another; at least their rapid motion, in all directions, from luminous bodies, seems to be owing to some such property.

³²¹
 Light ca-
 pable of en-
 tering bo-
 dies,

3. Light is capable of entering into bodies, and remaining in them, and of being afterwards extricated without any alteration. Father Beccaria, and several other philosophers, have shewn us by their experiments, that there are a great many substances which become luminous after being exposed to the light. This property was discovered by carrying them instantly from the light into a dark place, or by darkening the chamber in which they were exposed. Most of these substances, indeed, lose this property in a very short time, but they recover it again on being exposed to the light; and this may be repeated as often as we please. We are indebted to Mr Canton for some very interesting experiments on this subject, and for discovering a composition which possesses this property in a remarkable degree. He calcined some common oyster shells in a good coal fire for half an hour, and then pounded and sifted the purest part of them. Three parts of this powder were mixed with one part of the flowers of sulphur, and rammed into a crucible which was kept red hot for an hour. The brightest parts of the mixture were then scraped off, and kept for use in a dry phial well stopped. When this composition is exposed for a few seconds to the light, it becomes sufficiently luminous to enable a person to distinguish the hour on a watch by it. After some time it ceases to shine, but recovers this property on being again exposed to the light. Light then is not only acted upon by other bodies, but it is capable of uniting with them, and afterwards leaving them without any change.

It is well known that light is emitted during combustion; and it has been objected to this conclusion, that these bodies are luminous only from a slow and imperceptible combustion. But surely combustion cannot be suspected in many of Father Beccaria's experiments, when we reflect that one of the bodies on which they were made was his own hand, and that many of the others were altogether incombustible; and the phenomena observed by Mr Canton are also incompatible with the notion of combustion. His pyrophorus shone only in consequence of being exposed to light, and lost

that property by being kept in the dark. It is not exposure to light which causes substances capable of combustion at the temperature of the atmosphere to become luminous, but exposure to air. If the same temperature continues, they do not cease to shine till they are consumed; and if they cease, it is not the application of light, but of caloric, which renders them again luminous: but Canton's pyrophorus, on the contrary, when it had lost its property of shining, did not recover it by the application of heat, except it was accompanied by light. The only effect which heat had was to increase the separation of light from the pyrophorus, and of course to shorten the duration of its luminousness. Two glass globes, hermetically sealed, containing each some of this pyrophorus, were exposed to the light and carried into a dark room. One of them, on being immersed in a basin of boiling water, became much brighter than the other, but in ten minutes it ceased to give out light; the other remained visible for more than two hours. After having been kept in the dark for two days, they were both plunged into a basin of hot water; the pyrophorus which had been in the water formerly did not shine, but the other became luminous, and continued to give out light for a considerable time. Neither of them afterwards shone by the application of hot water; but when brought near to an iron heated so as scarcely to be visible in the dark, they suddenly gave out their remaining light, and never shone more by the same treatment: but when exposed a second time to the light, they exhibited over again precisely the same phenomena; even a lighted candle and electricity communicated some light to them. Surely these facts are altogether incompatible with combustion, and fully sufficient to convince us that light alone was the agent, and that it had actually entered into the luminous bodies.

It has been questioned, indeed, whether the light emitted by pyrophori be the same with that to which they are exposed. Mr Wilson has proved, that in many cases at least it is different, and in particular that on many pyrophori the blue rays have a greater effect than any other, and that they cause an extrication of red light. Mr de Groffer has shewn the same thing with regard to the diamond, which is a natural pyrophorus *. Still, however, it cannot be questioned that the luminousness of these bodies is owing to exposure to light, and that the phenomenon is not connected with combustion.

But light appears capable, not only of entering into bodies, but of combining with them chemically. The phenomena of the phosphori seem to be instances of this, and a great many facts concur to prove that light enters into the composition of oxygen gas. When vegetables grow in the light, they give out oxygen gas; but no oxygen is extricated in the dark, even though heat be applied †. From this it is evident, that the separation of this gas from plants, or perhaps the decomposition of the water which they contain, depends upon the action of light; and that as this decomposition is chemical, the light to produce it must either combine with the oxygen or the hydrogen, or at least contribute to the combination of some other substance with one or other of them. When the oxides of gold or silver are exposed to light, they are reduced to the metallic state ‡, and at the same time a quantity of oxygen gas is extricated.

Light.

* *Jour. de Phys.* xx. 270.

³²²
 And of be-
 ing combi-
 ned with
 them.

† *Priestley and Ingen-
 bouze.*

‡ *Scheele.*

Light.

cated*. In this case, it is evident that the light must either combine with the oxygen or the metals. If a quantity of nitric acid be exposed for some time to the light, it becomes yellow, as is well known, and a quantity of oxygen gas is found floating on its top. If it be now carried to a dark place, the oxygen is gradually absorbed, and the acid becomes colourless. In this case, nitric acid is decomposed by means of light, and resolved into *nitrous acid* and oxygen gas. The light must therefore have combined either with the nitrous acid or the oxygen. But no change whatever appears to have been produced in the nitrous acid; for if it be obtained in the dark by any other process, it has precisely the same properties. The oxygen, on the contrary, is converted into a *gas*. It is more probable, then, that the light has combined with the oxygen than with the acid. Hence there is reason to suspect that light makes one of the ingredients of oxygen gas. Caloric has already been shewn to make another ingredient.

³²³
Light which appears during combustion supposed combined with oxygen gas.

During combustion, a quantity of light as well as caloric is almost always evolved. We must conclude, therefore, that light makes a part of the composition either of the combustibles themselves, or of the oxygen gas with which they unite. We have already shewn that oxygen gas probably contains light; and this probability is confirmed by another fact. Substances may be combined with oxygen without the emission of any light, provided the oxygen be not in the state of a gas. If phosphorus, for instance, be put into nitric acid, it attracts oxygen, and is converted into phosphoric acid without the emission of any light. Now if the light which appears during combustion had been combined with the combustible, it ought to appear in all cases when that combustible is united with oxygen, whether the oxygen has previously been in the state of a gas or not. But as this is not the case, we may certainly infer, that the light which appears during combustion is extricated, not from the combustible, but from the oxygen gas. And this seems at present to be the opinion of the greater number of philosophers.

But we must acknowledge, that this conclusion is not without its difficulties, and difficulties, too, which, in the present state of chemistry, it does not seem possible to surmount.

³²⁴
Difficulties attending this opinion.

In the first place, it is evident, that light *may* be produced during combustion, though the oxygen be not in the state of a gas: For if nitric acid be poured upon oil of turpentine, the oil takes fire, and burns with the greatest rapidity, and a great deal of light is emitted. This combustion is occasioned by the oxygen of the acid combining with the ingredients of the oil. It follows, therefore, if the light emitted was previously combined with the oxygen, that oxygen must contain light when not in the state of a gas. Mr Proust has shewn that a great variety of similar combustions may be produced. But what is very remarkable, by proper caution the very same combinations may be made to take place without the visible emission of any light. In that case they take place very slowly, as happens also when phosphorus decomposes nitric acid; so that the emission or non-emission of light seems to depend not upon the state of the oxygen, so much as upon the rapidity or slowness of the combination. It is true, indeed, as the late Dr Hutton of Edinburgh observed, that light may be emitted in these slow combinations though it be not

visible; and this is very probably the case: but then the proof is destroyed that light exists in oxygen gas, from its not appearing during combinations in which the oxygen did not exist previously in a gaseous state.

Light.

In the second place, the colour of the light emitted during combustion differs almost always according to the combustible. During the combustion of phosphorus, tin, and zinc, the light emitted is white; during that of sulphur and bismuth, blue. Now if this light were united with the oxygen, why does it not appear always of the same colour, whatever be the combustible?

In the last place, the phenomena of phosphori shew that light is capable of entering into other bodies as well as oxygen gas; and the emission of light on the collision of two flint stones, when no oxygen gas can be decomposed, is a proof of the same kind, which cannot be got over.

In the present state of chemistry, therefore, it cannot be concluded, that the light emitted during combustion does not exist in the combustibles as well as in the oxygen.

4. Light has the property of heating bodies. All bodies, however, are not heated by it. Those which are perfectly transparent, or which allow all the light to pass through them, suffer no alteration in their temperature. Thus light may be concentrated upon water or glass without producing any effect. Neither does it produce much change upon those bodies (mirrors for instance) that reflect all or nearly all the light which falls upon them. And the smallness of the alteration of temperature is always proportional to the fineness of the polish, or, which is the same thing, to the quantity of light which is reflected. So that we have reason to conclude, that if a substance could be procured which reflected all the light that fell upon it, the temperature of such a substance would not be at all affected by light falling upon it. Dr Franklin exposed upon snow pieces of cloth of different colours (white, red, blue, black) to the light of the sun, and found that they sunk deeper, and consequently acquired heat, in proportion to the darkness of their colour. Now it is well known that dark-coloured bodies, even when equally exposed to the light, reflect less of it than those which are light-coloured. But since the same quantity falls upon each, it is evident that dark-coloured bodies must absorb and retain more of it than those which are light-coloured. That such an absorption actually takes place is evident from the following experiment. Mr Thomas Wedgwood placed two lumps of luminous or phosphorescent marble on a piece of iron heated just under redness. One of the lumps of marble which was blackened over gave out no light; the other gave out a great deal. On being exposed a second time in the same manner, a faint light was seen to proceed from the clean marble, but none at all could be perceived to come from the other. The black was now wiped off, and both the lumps of marble were again placed on the hot iron: The one that had been blackened gave out just as little light as the other*. In this case, the light which ought to have proceeded from the luminous marble disappeared: it must therefore have been stopped in its passage out, and retained by the black paint. Now black substances are those which absorb the most light, and they are the bodies which are most heated by exposure to light. Cavallo observed, that a

³²⁵
Light heats bodies.

* Phil. Trans. 1792

Light. thermometer with its bulb blackened stands higher than one which has its bulb clean, when exposed to the light of the sun, the light of day, or the light of a lamp*.

* *Flil. Trans.* 1780. Mr Pictet made the same observation; and took care to ascertain, that when the two thermometers were allowed to remain for some time in a dark place, they acquired precisely the same height. He observed, too, that when both thermometers had been raised a certain number of degrees, the clean one fell a good deal faster than the other †. But it is not a small degree of heat alone which can be produced by means of light. When its rays are concentrated by a burning-glass, they are capable of setting fire to combustibles with ease, and even of producing a temperature at least as great, if not greater, than what can be procured by the most violent and best conducted fires. In order to produce this effect, however, they must be directed upon some body capable of absorbing and retaining them; for when they are concentrated upon transparent bodies, or upon fluids, mere air for instance, they produce little or no effect whatever. We may conclude, therefore, in general, that in all cases when light produces heat it is absorbed.

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Heat renders bodies luminous,

5. All bodies become luminous when their temperature is raised a certain number of degrees. No fact is more familiar than this; so well known indeed is it, that little attention has been paid to it. When a body becomes luminous by being heated in a fire, it is said in common language to be *red hot*. It follows from all the experiments hitherto made, that the temperature at which they become red hot is nearly the same in all bodies.—It seems to be, pretty near 800°. A red hot body continues to shine for some time after it has been taken from the fire and put into a dark place. The constant accession, then, either of light or heat is not necessary for the shining of bodies: but if a red hot body be blown upon by a strong current of air, it ceases to shine immediately †. Consequently the moment the temperature of a body is diminished by a certain number of degrees, it ceases to be luminous.

† *T. Wedgwood, Phil. Trans.* 1792.

Whenever a body reaches the proper temperature, it becomes luminous, independent of any contact of air; for a piece of iron wire becomes red hot while immersed in melted lead §.

§ *Id. ibid.* 327
Except the gases.

To this general law there is one remarkable exception. It does not appear that the gases become luminous even at a much higher temperature. The following ingenious experiment of Mr T. Wedgwood seems to set the truth of this exception in a very clear point of view. He took an earthen ware tube B (fig. 5.), bent so in the middle that it could be sunk, and make several turns in the large crucible C, which was filled with sand. To one end of this tube was fixed the pair of bellows A; at the other end was the globular vessel D, in which was the passage F, furnished with a valve to allow air to pass out, but none to enter. There

was another opening in this globular vessel filled with glass, that one might see what was going on within. The crucible was put into a fire; and after the sand had become red hot, the air was blown through the earthen tube by means of the bellows. This air, after passing through the red hot sand, came into the globular vessel. It did not shine; but when a piece of gold wire E was hung at that part of the vessel where the earthen ware tube entered, it became faintly luminous. A proof, that though the air was not luminous, it had been hot enough to raise other bodies to the shining temperature.

6. Thus it appears that light and heat reciprocally produce each other; that the fixation of light in bodies always produces heat, and that the application of a sufficiently strong heat always occasions the extrication of light. Are heat and light, then, owing to the same cause? Does light become caloric merely by being fixed in bodies? and does caloric assume the appearance of light whenever it is extricated from them? In short, are caloric and light merely names for the same substance, called *caloric* when it is fixed in bodies, and *light* when in a state of liberty?

To these questions it may be answered, That if caloric and light were one and the same substance, they ought to produce precisely the same effects. Now this is not the case: a black body is not heated sooner by mere caloric than any other, though the contrary takes place when both are exposed to the light*. Heat cannot make growing vegetables exhale oxygen gas, though light does it almost instantaneously. When oxy-muriatic acid (a compound of oxygen and muriatic acid) is exposed to the light, a quantity of oxygen gas flies off, and nothing remains but common muriatic acid. Light then decomposes this acid; for if you wrap up a bottle in black cloth, so as to exclude light, and then expose it equally to the sun, no such decomposition takes place. Now this decomposition cannot be produced by mere caloric. If the acid be heated, it simply evaporates without being altered. Chaptal has proved (p), that the rays of light directed on certain parts of glasses, containing solutions of salts, cause them to crystallize in that part in preference to any other †. These observations have been confirmed and extended by Mr Dorthes ‡. Now caloric produces no such effects, nor has the temperature any influence on the phenomenon.

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Inquiry into the cause of these phenomena.

* *T. Wedgwood, Phil. Trans.* 1792

† *Mem. Toulouse*, iii.
‡ *Ann. de Chim.* ii.

32.

These facts are sufficient to shew that light and caloric, even when they have entered into bodies, produce different effects, and that therefore they have different properties (Q). But if the only difference between them were, that the one is in a state of liberty, the other in that of combination, the moment light entered a body it ought to be no longer light but caloric, and consequently ought to produce precisely the same effects with caloric: And since this is not the case, we are warranted surely to conclude that light and caloric are not the same, but

(p) Petit made the same observations in 1722. See *Memoirs of the Academy of Sciences* for that year, p. 95. and 331.

(Q) We must acknowledge, however, that the following ingenious experiments of Professor Pictet might be adduced, to prove that light and caloric possess at least one property in common, that of moving in straight lines.

He placed two concave mirrors of tin, of nine inches focus, at the distance of twelve feet two inches from one another. In the focus of one of them he placed a ball of iron two inches in diameter, heated so as not to be visible

Light.
329
Supposed
owing to
the mutual
repulsion
of light and
caloric.

but different substances (R). How then does caloric occasion the appearance of light, and light that of caloric?

We have seen already, that there is no body in nature which does not contain caloric; and light has such an influence upon every thing, it produces such important changes upon the animal and vegetable kingdoms, it can be extricated from such a vast number of bodies, that in all probability we may conclude with regard to it also, that it exists in all, or in almost all, the bodies in nature. We have no means of ascertaining either the quantity of light or of caloric that exists in bodies; but if we were to judge from the quantity which appears during combustion, we must reckon it very considerable. Now, may there not exist a repulsion between the particles of caloric and light? It is not easy, at least, to see why light flies off during combustion with such rapidity, if this be not the case. If such a repulsion actually exists, it will follow that caloric and light cannot be accumulated in the same body beyond a certain proportion. If the caloric exceed, it will tend to drive off the light; if the light, on the contrary, happens to prevail, it will displace the caloric.

If caloric and light actually exist in all bodies, there must be an affinity between them and all other bodies; and this affinity must be so great, as to render ineffectual the repulsion which exists between light and caloric. Let us suppose now, that these two substances exist in all bodies in certain proportions, it will follow, that the

more either of caloric or light is added to any body, the stronger must the repulsion between their particles become; and if the accumulation be still going on, this repulsion will soon become great enough to balance their affinity for the body in which they exist, and consequently will dispose them to fly off. If caloric, for instance, be added to a body, whenever the body arrives at a certain temperature it becomes luminous, because part of the light which was formerly combined with it is driven off. This temperature must depend partly upon the affinity between the body and caloric, and partly upon its affinity for light. Pyrophori, for instance, the affinity between which and light does not seem to be very great, become luminous at a very moderate temperature. This is the case with the pyrophorus of Canton. A great many hard bodies become luminous when they are exposed to a moderate heat; fluor, for instance, carbonat of barytes, spar, sea-shells, and a great many others, which are enumerated by Mr Thomas Wedgwood*.

* *Phil. Trans.* 1792, p. 2.
The same ingenious gentleman has observed, that gold, silver, copper, and iron, become luminous when heated in times inversely proportional to their specific caloric †. Now the specific caloric of these metals † *Ibid.*

Iron,
Copper,
Silver,
Gold.

They

visible in the dark; in the other was placed the bulb of a thermometer. In six minutes the thermometer rose from 4° to 14° (*Reaumur*). A lighted candle, which was substituted for the ball of iron, made the thermometer rise in one experiment from $4,6^{\circ}$ to 14° ; in another, from $4,2^{\circ}$ to $14,3^{\circ}$. In this case both light and heat appeared to act. In order to separate them, he interposed between the two mirrors a plate of clear glass. Before the interposition of the glass, the thermometer had risen from 2° to 12° , where it was stationary. After the interposition of the glass it sunk in nine minutes to $5,7^{\circ}$; and when the glass was again removed it rose in seven minutes to $11,1^{\circ}$; yet the light which fell on the thermometer did not seem at all diminished by the glass. Mr Pictet therefore concluded, that the caloric had been reflected by the mirror, and that it had been the cause of the rise of the thermometer. In another experiment, a glass matras was substituted for the iron ball, nearly of the same diameter with it, and containing 2044 grains of boiling water. Two minutes after a thick screen of silk, which had been interposed between the two mirrors, was removed, a Fahrenheit's thermometer, which was in the other focus, rose from 47° to $50\frac{1}{3}^{\circ}$; and the moment the matras was removed from the focus the thermometer again descended. On repeating the experiment, with this variation, that the bulb of the thermometer was blackened, it rose from $51\frac{1}{3}^{\circ}$ to $55\frac{1}{3}^{\circ}$.

The mirrors of tin were now placed at the distance of 90 inches from each other; the matras with the boiling water in one of the foci, and a very sensible air thermometer in the other, every degree of which was equal to $\frac{1}{3}$ th of a degree of *Reaumur*. Exactly in the middle space between the two mirrors, there was placed a very thin common glass mirror, suspended in such a manner that either side could be turned towards the matras. When the polished side of this mirror was turned to the matras, the thermometer rose only $0,5^{\circ}$; but when the side covered with tinfoil, and which had been blackened with ink and smoke, was turned toward the matras, the thermometer rose $3,5^{\circ}$. In another experiment, when the polished side of the mirror was turned to the matras the thermometer rose 3° , when the other side $9,2^{\circ}$. On rubbing off the tinfoil, and repeating the experiment, the thermometer rose 18° . On substituting for the glass mirror a piece of thin white pasteboard of the same dimensions with it, the thermometer rose 10° . On putting a matras full of snow into one of the foci (the mirrors in this experiment were $10\frac{1}{2}$ feet distant from each other), the air thermometer *sunk* several degrees, and rose again when the matras was removed. When nitric acid was poured on the snow, the thermometer sunk 5° or 6° lower.

Taking it for granted that these experiments proved the motion of caloric in straight lines like light, Mr Pictet endeavoured to discover the velocity of its motion. For this purpose he placed two concave mirrors at the distance of 69 feet from each other; the one of tin as before, the other of plaster gilt, and 18 inches in diameter. Into the focus of this last mirror he put the air thermometer, and the bullet of iron heated as before into that of the other. A few inches from the face of the tin mirror there was placed a thick screen, which was removed as soon as the bullet reached the focus. The thermometer rose the instant the screen was removed, without any perceptible interval: hence he concluded, that the time caloric takes in moving 69 feet is too short to be measured. See *Pictet sur le Feu*, chap. iii.

(R) See more on this subject under *THERMOMETRIC Spectrum* in this Supplement.

Light. They become luminous, therefore, when exposed to the same degree of heat, in the following order :

Gold,
Silver,
Copper,
Iron.

Now the smaller the specific caloric of any body is, the less must be the quantity of caloric necessary to raise it a given number of degrees ; the sooner therefore must it arrive at the temperature at which it gives out light. It was natural to expect, then, if the emission of light from a body by the application of heat be owing to the repulsion between caloric and light, that those bodies should become luminous soonest in which that repulsion increases with the greatest rapidity ; and this we see is precisely the case. The only question to be determined before drawing this conclusion is, Whether the same quantity of caloric entered all of them ? That depends upon their conducting power, which, according to Ingenhoufz, is in the following order :

Silver,
Gold,
Copper,
Iron.

We see, then, that this conducting power is nearly in the order in which these metals become luminous ; so that the greatest quantity of caloric would enter those which become soonest luminous. Now this is just what ought to happen, provided the expulsion of light from a luminous body, by the application of heat, be owing to the repulsion between the particles of caloric and light.

The repulsion between the different rays of light and caloric does not seem to be equal ; the repulsion between the blue rays and caloric seems to be greater than that between the red rays and caloric ; and the repulsion between all the rays and caloric seems to be directly as their refrangibility : accordingly, when heat is applied to a body, the blue rays escape sooner, and at a lower temperature, than the red rays and others which are most refrangible. When sulphur, for instance, is burnt at a low temperature, the colour of the flame is blue ; and when examined by the prism, it is found to consist of the violet, indigo, blue, and sometimes of a small quantity of the green rays* ; but when this substance is burnt at a high temperature, the colour of the flame is white, all the rays separating together. When bodies have continued to burn for some time, they may be supposed to have lost the greater part of the most refrangible rays ; hence the red appearance of bodies, charcoal for instance, that have burnt for some time, the only rays which remain to separate being the orange, yellow, and red †.

The blue rays seem not only to repel caloric with greater force, but likewise to have a greater affinity for other bodies than the red rays have ; for they decompose the oxide of silver (or rather the muriat of silver) much sooner, and to a greater extent, than the red rays ‡ : hence we see the reason why the application of

the blue rays to Mr Wilson's pyrophori and to the diamond causes an extrication of red rays.

We have seen already, that the gases are not heated red hot by the application of heat. It would follow from this, that the gases do not contain light : but the contrary is certain ; for light is actually extricated during the combustion of hydrogen, and must therefore have existed either in the oxygen or hydrogen gas, or in both. Probably therefore the reason that heat does not extricate light from the gases is, that the affinity between their bases and light is exceedingly strong : it would therefore require a more than usual temperature to produce its extrication ; and on account of the great dilatibility of these gases, which always tends to diminish the repulsion between the caloric and light, this temperature cannot be applied. It is easy to see, upon the supposition that there exists a repulsion between caloric and light, why the accumulation of light should produce heat, and why light only occasions heat in those bodies that absorb it.

Such is the theory of the cause of the reciprocal extrication of light and caloric by the application of these substances respectively to bodies, which has been proposed by several ingenious chemists (s) ; and we acknowledge frankly, that it appears to us by far the most plausible of all the explanations of this phenomenon with which we are acquainted.

It is not, however, beyond the reach of objections, and objections too, we are afraid, altogether incompatible with its truth. Were the repulsion between caloric and light the only cause of the luminousness of hot bodies, the continual application of heat would surely in time separate the whole of the light which was combined with the body, and then it would cease to be luminous altogether ; but we have no reason to suppose that bodies ever cease to become luminous by the continued application of heat. Claveus kept melted, and consequently red hot, gold for months in a furnace ; but he does not say that its luminousness was diminished, far less destroyed ; and had such a remarkable phenomenon taken place, certainly he would not have failed to inform us ; but so far from that, he expressly says that it suffered no alteration (τ) §.

Whether light would continue to extricate a great deal of caloric during so long a time, has never been tried ; but we have no reason for supposing that its power to produce that effect is ever exhausted ; for bodies, after being exposed to the sun for years, and even for ages, are just as much heated by it as ever. But these effects, far from being inexhaustible, ought, according to the theory, to come very speedily to an end. It is certainly probable, then, as other philosophers have supposed, that though light and caloric are not precisely one and the same substance, they are some how or other intimately connected, and are either composed of different proportions of the same ingredients, or the one enters into the composition of the other.

One

(s) Particularly by Dr Parr, who is said to be the author of a paper on this subject, published in the *Exeter Memoirs*.

(τ) A gentleman, to whom we mentioned this objection, observed, that in the case of bodies long exposed to heat, the light which appears to proceed from them, might, in fact, be extricated from the atmosphere by the caloric communicated to it from the heated body. This thought is new and ingenious, and might easily be put to the test of experiment. Some of the facts mentioned in the text are rather hostile to it ; but should it prove well founded, it would go far to remove most of the difficulties in which the theory of light is at present involved.

* Morgan, *Phil. Trans.* 1785.

† *Ibid.*

‡ *Sennebier*.

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Objections to which this theory is liable.

§ Shaw's Boyle, iii. 268.

Light.
 331
 Scheele's
 theory of
 light and
 caloric.
 * In his
*Treatise on
 Fire.*

One of the first theories of this kind (for the opinion of Stahl has been already discussed) was formed by Mr Scheele*, one of the most extraordinary men and greatest philosophers that ever existed. Without the assistance of education or of wealth, his genius burst forth with astonishing lustre; and at an age when most philosophers are only rising into notice, he had finished a career of discoveries which have no parallel in the annals of chemistry. Whoever wishes to behold ingenuity combined with simplicity, whoever wishes to see the inexhaustible resources of chemical analysis, whoever wishes for a model in chemical researches—has only to peruse and to study the works of Scheele (τ). After a vast number of experiments, conducted with astonishing ingenuity, he concluded, that caloric was composed of a certain quantity of oxygen combined with phlogiston; that radiant heat, a substance which he supposed, capable of being propagated in straight lines like light, and not capable of combining with air, was composed of oxygen united with a greater quantity of phlogiston, and light of oxygen united with a still greater quantity. He supposed, too, that the difference between the rays depended upon the quantity of phlogiston: the red, according to him, contained the least; the violet, the most phlogiston. By *phlogiston* Mr Scheele seems to have meant *hydrogen*. It is needless therefore to examine his theory, as it is now known that the combination of hydrogen and oxygen forms not caloric but water (υ). The whole fabric therefore has tumbled to the ground; but the importance of the materials will always be admired, and the ruins of the structure shall remain eternal monuments of the genius of the builder.

332
 De Luc's
 theory.
 † In his
*Idées sur la
 Météoro-
 logie.*

Mr de Luc, so well known for his important meteorological labours, has advanced another theory †. According to him, light is a body which moves constantly in straight lines, with such rapidity that its gravitation towards other substances bears no sensible proportion to its motion. Light has the property of combining with another unknown substance, and the compound formed is caloric, which possesses very different properties from light. Caloric is constantly describing helicoidal curves round an axis, which accounts for the slowness of its apparent motion. Light produces or increases heat, partly by increasing the expulsive power of caloric, and

partly by combining with the *unknown substance*, and forming new caloric; caloric, on the other hand, is always decomposed when bodies become luminous. This theory is certainly ingenious, and would remove many of the difficulties which we at present labour under in attempting to explain the phenomena of caloric and light. It is, however, liable to other difficulties which could not be easily surmounted. But it is needless to examine these, as the theory itself is supported by no evidence whatever, and cannot therefore be admitted.

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Another theory has been advanced by the late Dr Hutton's theory. Hutton of Edinburgh (ν); a man of undoubted genius, but of rather too speculative a turn of mind, and who sometimes involved himself in difficulties from his very ingenuity. All his writings display evident marks of the profound philosopher: they contain much instruction; and even his mistakes are not without their use: but unfortunately his manner is so peculiar, that it is scarcely more difficult to procure the secrets of science from Nature herself, than to dig them from the writings of this philosopher. He supposes that there are two kinds of matter, gravitating matter and light; the last of which wants gravity, and consequently neither possesses magnitude (w) nor momentum. Light has the power of being fixed in bodies; and then it becomes either caloric or phlogiston, which differs in some particulars from caloric, but in what, the Doctor does not precisely tell us.

Part of this theory we have examined already when we attempted to prove that light and caloric were different substances. The other part of the theory seems to involve a contradiction; for how could light become fixed in a body, unless it were attracted by it? and if light possesses attraction, it surely cannot be destitute of gravity; for what is gravity but *attraction* (x)?

Thus, notwithstanding the ingenuity of the philosophers who have attempted to investigate this part of chemistry, the connection between light and caloric is still unknown. We must content ourselves, therefore, with considering them at present as distinct substances, and leave the solution of the many difficulties which at present perplex us to the more happy labours of future inquirers.

PART

(τ) This Newton of chemistry died in 1786, at the age of 44. His moral character, according to Mr Erhart and others, who were the companions of his youth, and Messrs Gadolin, Espling, and those who knew him in his latter days, was irreproachable and praise worthy. His outward appearance was not expressive of the great mind which lay concealed as it were under a veil. He seldom joined in the usual conversations and amusements of society, having as little leisure as inclination to do so; for what little time he had to spare from the hurry of his profession (an apothecary), was constantly filled up in the prosecution of experiments. It was only when he received visits from his friends, with whom he could converse upon his favourite science, that he indulged himself in a little relaxation. For such friends he had a sincere affection, as he had also for those that lived at a distance, and even for such as were not personally known to him. He kept up a regular correspondence with Messrs Erhart, Meyer, Kirwan, Crell, and several other chemists. See *Crell's Life of Scheele*.

(υ) This candid philosopher afterwards acknowledged, that the proofs for the composition of water were complete: but we do not know exactly how he attempted to reconcile his theory of heat with the belief that water was composed of oxygen and hydrogen; two opinions which are certainly incompatible.

(w) See his dissertations on different subjects of natural philosophy.

(x) Indeed Dr Hutton refused this property to gravitating matter also; following, in this particular, the theory of the celebrated Boscovich.

(y) We hope not to be accused of disputing merely about the meaning of a word, till what is said on this subject in the chapter of the present article, which treats of *Affinity*, has been examined.

PART II. OF COMPOUND BODIES.

Water. TO those bodies which are composed of *two simple substances* combined together, for want of a better name we have given the appellation of *compound bodies*. They may be reduced under five classes:

1. Water,
2. Alcohol,
3. Oils,
4. Alkalies,
5. Acids.

These shall be the subject of the five following chapters; and we shall finish this part of the article with some observations on *Affinity*.

CHAP. I. Of WATER.

WATER is a well-known liquid, found in abundance in every part of the world, and absolutely necessary for the existence of animals and vegetables.

When pure, in which state it can be obtained only by distillation, it is transparent, and destitute of colour, taste, and smell.

³³⁴ **Weight of water.** A cubic foot of water, at the temperature of 55°, weighs, according to the experiments of Professor Robison of Edinburgh (see *SPECIFIC Gravity*, Encycl.), 998,71 avoirdupois ounces, of 437,5 grains troy each, or only 1,26 ounces less than 1000 avoirdupois ounces; so that rain water, at the same temperature, will weigh pretty nearly 1000 ounces. The specific gravity of water is always supposed = 1,000, and it is made the measure of the specific gravity of every other body.

³³⁵ **Ice.** When water is cooled down to 32°, it assumes the form of ice. If this process goes on very slowly, the ice assumes the form of crystalline needles, crossing each other at angles either of 60° or 120°, as Mr de Mairan has remarked; and it has been often observed in large crystals of determinate figures. Ice, while kept at a temperature considerably below 32°, is very hard, and may be pounded into the finest dust. It is elastic. Its specific gravity is less than that of water.

³³⁶ **Steam.** When water is heated to the temperature of 212°, it boils, and is gradually converted into steam. Steam is an invisible fluid like air, but of a less specific gravity. It occupies about 1200 times the space that water does. Its elasticity is so great, that it produces the most violent explosions when confined. It is upon this principle that the steam-engine has been constructed. See *STEAM* and *STEAM-Engine*, Encycl.

³³⁷ **Boiling point of water.** The phenomena of boiling are owing entirely to the rapid formation of steam at the bottom of the vessel. The boiling point of water varies according to the pressure of the atmosphere. In a vacuum water boils at 90°; and when water is confined in Papin's digester, it may be almost heated red hot without boiling. The mixture of various salts with water affects its boiling point considerably. Mr Achard made a number of experiments on that subject; the result of which may be seen in the following Tables*:

³³⁸ **Impregnated with various salts.**

* *Transf. Berlin*, 1785.

CLASS I. Salts which do not affect the Boiling Point.

Sulphat of copper.

CLASS II. Salts which raise the Boiling Point.

A saturated solution of	{	Muriat of soda	} Raises the boiling point	{	10,35°
		Sulphat of soda			5,6
		Sulphat of potash			0,9

A saturated solution of	{	Nitrat of potash	} Raises the boiling point	{	3,5°
		Boracic acid			2,2
		Carbonat of soda			2,35

Water.

This augmentation varies with the quantity of salt dissolved. In general, it is the greater the nearer the solution approaches to saturation.

CLASS III. Salts which lower the Boiling Point.

Borax,	{	In a small quantity, lowers the boiling point	}	}	1,350°
		Saturated solution of,			0,22
Sulphat of magnesia,	{	In a small quantity,	}	}	2,47
		Saturated solution of			1,1
Alum,	{	A very small quantity of,	}	}	0,0
		A greater quantity,			0,7
		A saturated solution of,			0,0
Sulphat of lime,	}	in any proportion,	}	}	2,02
Sulphat of zinc,					0,45
Sulphat of iron,					0,22
Acetite of lead,					1,24

CLASS IV.

Muriat of ammonia,	{	Small quantity of, lowers the boiling point	}	}	0,45
		Saturated solution of, raises do.			9,79
Carbonat of potash,	{	Small quantity of, lowers do.	}	}	0,45
		Saturated solution of, raises do.			11,2

Water was once supposed to be incompressible, but the contrary has been demonstrated by Mr Canton. The Abbé Mongez made a number of experiments, longer than that philosopher, on the same subject, and obtained similar results.

Water was believed by the ancients to be one of the four elements of which every other body is composed; and, according to Hippocrates, it was the substance which nourishes and supports plants and animals. That water was an unchangeable element continued to be believed till the time of Van Helmont, who made plants grow for a long time in pure water: From which experiment it was concluded, that water was convertible into all the substances found in vegetables.—Mr Boyle having digested pure water in a glass vessel hermetically sealed for above a year, obtained a quantity of earthy scales; and concluded, in consequence, that he had converted it partly into an earth*. He obtained the same earth by distilling water in a tall glass vessel over a slow fire †. Margraf repeated the experiment with the same result, and accordingly drew the same conclusion. But the opinion of these philosophers was never very generally received. The last person who embraced it was probably Mr Wafelton, who published his experiments on the subject in the *Journal de Physique* for 1780. Mr Lavoisier had proved, as early as 1773, that the glass vessels in which the distillation was performed lost a weight exactly equal to the earth obtained. Hence it follows irresistibly, that the appearance of the earth, which was silica, proceeded from the decomposition of the vessels; for glass contains a large proportion of silica. It has been since shewn by Dr Priestley, that water always decomposes glass when applied to its surface for a long time in a high temperature.

We have formerly mentioned, that water is composed of oxygen and hydrogen. This great discovery has

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^{Water.} contributed more perhaps than any other to the advancement of the science of chemistry, by furnishing a key for the explanation of a prodigious number of phenomena. The evidence, therefore, on which it rests, and the objections which have been made to it, deserve to be examined with peculiar attention.

³⁴¹ History of the discovery of its composition. The first person probably who attempted to discover what was produced by burning hydrogen gas was Scheele. He concluded, that during the combustion oxygen and hydrogen combined, and that the product was caloric.

In 1776 Macquer, assisted by Sigaud de la Fond, set fire to a bottle full of hydrogen gas, and placed a saucer above the flame, in order to see whether any fuliginous smoke would be produced. The saucer remained perfectly clean; but it was moistened with drops of a clear liquid, which they found to be pure water*.

* Macquer, *Dictionary*, art. *Gas, inflammable*. Next year Bucquet and Lavoisier exploded oxygen and hydrogen gas, and made an attempt to discover what was the product; about the nature of which they had formed different conjectures. Bucquet had supposed that it would be carbonic acid gas; Lavoisier, on the contrary, suspected that it would be sulphuric or sulphurous acid. What the product was they did not discover; but they proved that no carbonic acid gas was formed, and consequently that Mr Bucquet's hypothesis was ill founded †.

† *Mem. Par.* 1781, 470. In the beginning of the year 1781, Mr Warltire, at the request of Dr Priestley, fired a mixture of these two gases contained in a copper vessel; and observed, that after the experiment the weight of the whole was diminished. Dr Priestley had previously, in the presence of Mr Warltire, performed the same experiment in a glass vessel. This vessel became moist in the inside, and was covered with a foamy substance ‡, which Dr Priestley afterwards supposed to be a part of the mercury used in filling the vessel §.

‡ *Priestley*, v. 395. § *Phil. Trans.* lxxiv. 332. In the summer of 1781, Mr Henry Cavendish, who had been informed of the experiments of Priestley and Warltire, set fire to 500,000 grain measures of hydrogen gas, mixed with about 2½ times that quantity of common air. By this process he obtained 135 grains of pure water. He also exploded 19,500 grain measures of oxygen gas with 37,000 of hydrogen gas, and obtained 30 grains of water, containing in it a little nitric acid. From these experiments he concluded that water was a compound.—Mr Cavendish must therefore be considered as the real discoverer of the composition of water. He was the first who ascertained that water was produced by firing oxygen and hydrogen gas, and the first that drew the proper conclusion from that fact. Mr Watt, indeed, had also drawn the proper conclusion from the experiments of Dr Priestley and Mr Warltire, and had even performed a number of experiments himself to ascertain the fact, before Mr Cavendish had communicated his; but he had been deterred from publishing his theory by some experiments of Dr Priestley, which appeared contrary to it ||. He has therefore a claim to the merit of the discovery; a claim, however, which does not affect Mr Cavendish, who knew nothing of the theory and experiments of that ingenious philosopher.

|| *Ibid.* lxxv. 330.

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Water. Meanwhile, in the winter 1781-2, Mr Lavoisier, who had suspected that when oxygen and hydrogen gas were exploded, sulphuric or sulphurous acid was produced, made an experiment in order to ascertain the fact, at which Mr Gingembre assisted. They filled a bottle, capable of holding six pints (French), with hydrogen gas, to which they set fire, and then corked the bottle, after pouring into it 2 oz. (French) of lime-water. Through the cork there passed a copper tube, by means of which a stream of oxygen gas was introduced to support the flame. Though this experiment was repeated three times, and instead of lime-water a weak solution of alkali and pure water were substituted, they could not observe any product whatever*. This result astonished Mr Lavoisier exceedingly: he resolved, therefore, to repeat the experiment on a larger scale, and if possible with more accuracy. By means of pipes furnished with stop-cocks, he put it in his power to supply both gases as they should be wanted, that he might be enabled to continue the burning as long as he thought proper.

The experiment was made by Lavoisier and La Place on the 24th of June 1783, in the presence of Messrs Le Roi, Vandermonde, several other academicians, and Sir Charles Blagden, who informed them that Mr Cavendish had already performed it, and that he had obtained water †. They continued the inflammation till all their stock of gases was wasted, and obtained about 295 grains of water, which, after the most rigid examination, appeared to be perfectly pure. From this experiment Lavoisier concluded, that water was composed of oxygen and hydrogen. Mr Mongé soon after performed the same experiment, and obtained a similar result: and it was soon after repeated again by Lavoisier and Meusnier on a scale sufficiently large to put the fact beyond doubt ‡.

† *Ibid.* P. 474. The proofs that water is a compound are of two kinds; it has been actually composed, and it has been decomposed.

‡ *Ibid.* P. 474. With regard to the composition of water, we shall relate the celebrated experiment made by Lavoisier and Meusnier in the month of February 1785, in the presence of a numerous deputation from the academy of sciences, and so many other spectators, that it may be considered as having been performed in public. Every precaution was taken to ensure success. The gases had been prepared with care, and held for some time over a solution of potash, in order to deprive them of any acidity which they might accidentally contain; and before entering into the glass globe where they were to be burnt, they were made to pass over newly calcined potash, to deprive them of the water which they might happen to retain in solution. The hydrogen gas had been obtained by passing steam through iron at a white heat; the oxygen gas was procured from the red oxide of mercury. The combustion took place in a large glass globe, into which the gases were admitted by means of tubes furnished with stop-cocks; and the most ingenious contrivances were employed to ascertain exactly the quantities of each which were consumed (v). The whole machine is described at large by Mr Meusnier in the Memoirs of the Academy of Sciences for 1782.

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The

(v) A variety of instruments have been invented by the French chemists for that purpose. These instruments they have denominated *Gazometers*.

Water.

Water.

The quantities of gas employed, after deducting the 432 grains of residuum which were not consumed, were 2794,76 grains of oxygen gas, and 471,125 of hydrogen gas. After taking from these 32,25 grains, = the humidity of which the oxygen gas was deprived by the calcined potash, and 44,25 grains, = the weight which the hydrogen lost by the same process, there remains altogether 3188,4 grains of gas.

The quantity of water obtained amounted to 3219 grains; the specific gravity of which was to distilled water as 1,0051 to 1. This quantity was 30 grains more than the gas employed. The difference, no doubt, was owing to a small error in estimating the weight of the gases; which indeed it is extremely difficult to avoid, as the weight is altered by the smallest difference of temperature. This water had a slight smell, and a taste sensibly acid; it reddened slightly blue paper, and effervesced with the carbonat of potash. 1152 grains of that water being saturated with potash, and evaporated to dryness, left 20 grains of a salt which melted on the fire like nitre. It follows from this experiment, that the quantity of acid contained in the whole water would not have been quite sufficient to have formed 56 grains of nitre.

The residuum weighed, as has been already observed, 432 grains; its volume was equal to 444 grains of oxygen gas; it was diminished by nitrous gas (z) precisely as gas would be which contained 0,24 parts of oxygen; it rendered lime-water somewhat turbid, which indicated the presence of carbonic acid gas.

From the comparison of the weights, and volumes of the gases consumed, it was concluded that water consists of 0,85 parts, by weight, of oxygen, and 0,15 of hydrogen.

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Experi-
ment of Le
Fevre de
Gineau.

This experiment was soon after repeated by Mr Le Fevre de Gineau upon a still larger scale, and in the presence of a great number of spectators. It continued for no less than 12 days, and was performed with the most rigorous exactness of which experiments of that nature will admit*.

* Journ. de
Pby. 1788,
p. 457.

The oxygen gas employed, which had been procured from the black oxide of manganese, occupied the space of 35085,1 cubic inches, and weighed 18298,5 grains.

The hydrogen gas was obtained by dissolving iron in diluted sulphuric acid. Its volume was 7496,7 cubic inches, and its weight 4756,3 grains.

	Grains.
The two gases therefore amounted to	23054,8
From which taking the residuum after combustion, which amounted to	2831,0
There remains for the quantity consumed	20223,8
The water found in the glass globe after the combustion amounted to	20139,0
And there were carried off by the residuum	54,0
In all	20193,0

Which is just 30 grains less than the weight of the gases which disappeared, or $\frac{1}{877}$ part of their weight. This difference arose from the same difficulties which attended the experiment of Lavoisier. As the errors are on different sides, we are warranted to conclude that this

was the case, and that it was not owing to any real difference between the gases and the product.

The water was examined in the presence of Messrs Lavoisier, Le Roi, Mongé, Berthollet, Bayen, and Pelletier. Its specific gravity was to that of distilled water as 1,001025 to 1. It contained no sulphuric nor muriatic acids; yet it had an acid taste, and converted vegetable blues to a red. 6606 grains of it required for saturation 36 grains of carbonat of potash, and furnished by evaporation 26,5 grains of crystals of nitre. The whole water, therefore, would have required 109,7 grains of carbonat of potash for saturation.

This water affected lime-water a little; and it was found that the residuum of the gas contained some carbonic acid gas. This residuum formed a 19th part of the volume of the two gases employed, and an eighth of their weight. It contained 462 grains of carbonic acid gas, or about $\frac{1}{2}$ th part; the rest was azotic gas, with about $\frac{1}{2}$ th of oxygen.

This experiment gave the proportions of oxygen and hydrogen in water as follows:

Oxygen	,848
Hydrogen	,152
	1,000

This is so near the determination of Mr Lavoisier, that it must be considered as a very strong confirmation of it.

In the year 1790, another similar experiment was performed by Seguin, Fourcroy, and Vauquelin, in the presence of a number of commissioners appointed by the Academy of Sciences. Every precaution was taken to ascertain the quantity of gas employed with the utmost exactness, and to exclude all atmospheric air as completely as possible.

The hydrogen gas was procured by dissolving zinc in sulphuric acid diluted with 7 parts of water. The oxygen gas was obtained by distilling oxy-muriat of potash (A).

The quantity of hydrogen gas employed amounted to 862,178 grains troy. The quantity of oxygen gas amounted to 13475,198 cubic inches (French). Its purity was such, that it contained three cubic inches of azotic gas in the 100. The whole gas, therefore, contained 404,256 cubic inches. There were likewise in the glass vessel in which the combustion took place 15 cubic inches (French) of atmospheric air, which consisted of 11 cubic inches of azotic and four of oxygen gas. So that the whole oxygen gas employed amounted to 13074,942 cubic inches; and it contained besides 415,256 cubic inches of azotic gas. They ascertained by experiment, that a cubic inch of this oxygen gas, thus diluted with $\frac{1}{877}$ of azot, weighed ,4040 of a grain troy. Now, according to the experiments of Lavoisier, a cubic inch (French) of azotic gas weighs only ,3646 of a grain troy. Consequently the weight of pure oxygen gas is greater than ,4040; and by calculation they shewed it to amount to ,4051 of a grain troy. The weight of the whole oxygen gas employed, therefore, was 5296,659 grains troy; and that of the azotic gas mixed with it 151,402 grains troy.

The

(z) This gas shall be afterwards described. It has the property of absorbing almost instantaneously the oxygen gas with which it comes into contact. It is therefore often used, in order to discover how much oxygen gas exists in any mixture.

(A) A salt composed of oxy-muriatic acid and potash.

CHEMISTRY.

Part II.

Water. The combustion continued 185 hours; and during all that time our philofophers never quitted the laboratory. The flame was exceedingly small, and the heat produced by no means great. This was owing to the very small stream of hydrogen, which was constantly flowing into the vessel.

The water obtained amounted to 5943,798 grains troy, or 12 oz. 7 dwts. and 15,798 grains. It exhibited no mark of acidity, and appeared in every respect to be pure water. Its specific gravity was to that of distilled water as 18671 to 18670; or nearly as 1,00053 to 1.

The residuum of gas in the vessel after combustion amounted to 987 cubic inches (French); and on being examined, was found to consist of the following quantities of gases:

Azotic gas, - - - - -	467 cubic inches.
Carbonic acid gas, - - - - -	39
Oxygen gas, - - - - -	465
Hydrogen gas, - - - - -	16
<hr/>	
Total - - - - -	987

The weight of which is as follows:

Azotic gas, - - - - -	170,258 gr. troy.
Carbonic acid gas, - - - - -	23,306
Oxygen gas, - - - - -	188,371
Hydrogen gas, - - - - -	0,530
<hr/>	
Total, - - - - -	382,465

Now the weight of the whole gases employed was, - - - - - 6310,239 gr. troy.
 That of the water obtained, and of the residuum, - - - - - 6326,263

Or - - - - - 16,024 grains

more than had been employed. This small quantity must have been owing to common air remaining in the tubes, and other parts of the apparatus, in spite of all the precautions that were taken to prevent it; if it did not rather proceed from unavoidable errors in their valuations.

The quantity of azotic gas introduced was	151,178
The quantity found in the residuum was	170,258
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There was therefore a surplus of - - - 19,080 gr.

As sufficient precautions had been taken to prevent the introduction of carbonic acid gas, the quantity found in the residuum must have been formed during the process. There must therefore have been a small quantity of carbon introduced. Now zinc often contains carbon, and hydrogen has the property of dissolving carbon: probably, then, the carbon was introduced in this manner. The carbonic acid found in the residuum amounted to 23,306 grains, which, according to Lavoisier's calculation, is composed of 8,958 grains of carbon, and 14,348 grains of oxygen.

Subtracting these 8,958 grains of carbon, and the ,530 of a grain of hydrogen, which remained in the vessel, from the total of hydrogen introduced, there will remain 852,690 grains for the hydrogen that disappeared.

Subtracting the 14,348 grains of oxygen which entered into the composition of the carbonic acid, and the residuum of oxygen, which amounted to 188,371 grains, the quantity of oxygen that disappeared will amount to 5093,940 grains.

Hydrogen that disappeared, -	852,690 gr. troy.	Water.
Oxygen, - - - - -	5093,940	
<hr/>		
Total, - - - - -	5946,630	
Quantity of water obtained, -	5943,798	

Which is less than the gases consumed by - - - - - 2,832 grains *.

* Ann. de Chim. viii. Such are the principal experiments upon which the opinion is founded that water is a compound. Let us examine them, and see whether they are sufficient to establish that opinion. The circumstances which chiefly claim our attention, and which have been chiefly insisted on, are these:

1. The whole of the gases was not consumed.
2. In the residuum were found several substances which were not introduced, and which must therefore have been formed during the combustion.
3. The water obtained was seldom perfectly pure. It generally contained some nitric acid.
4. As only part of the gases were consumed, and as all gases contain water in them, might not the gas which disappeared have been employed in forming the other substances found in the residuum? and might not the water obtained have been merely what was formerly dissolved in the gases, and which had been precipitated during the experiment?

That the whole of the gases was not consumed will not surprise us, if we recollect that it is impossible for that to take place, allowing them to be perfectly pure, except they be mixed in precisely the proper proportions; and not even then, except every particle of them could be raised to the proper temperature. Now how can this be done in experiments of that nature?

But how is it possible to procure a large quantity of gas completely pure? And supposing it were possible, how can every particle of atmospheric air be excluded? In the last experiment, notwithstanding every precaution, 15 cubic inches (French) were admitted; and there is reason to believe from the results, that the quantity was even considerably greater than this. But if any atmospheric air be admitted, there must be a residuum of azotic gas.

In the first experiment, it had been previously ascertained that the oxygen gas employed contained $\frac{1}{4}$ th of azotic, or about 233,05 grains; and the residuum contained at most 329,1 grains, or 96,05 grains more than what had for certain pre-existed in the gases.

In the second experiment, the azot in the residuum amounted at most to $\frac{1}{4}$ th of the oxygen gas employed. But the oxygen was procured from the black oxide of manganese, which always yields a quantity of azot as well as of carbonic acid. It has been ascertained, that the azot, mixed with oxygen gas procured in that manner, often exceeds $\frac{1}{4}$ th.

In the third experiment, the azotic gas found in the residuum amounted to 170,258 grains; and the quantity contained in the gases before combustion amounted to 151,178 grains: the surplus, therefore, amounted to 19,08 grains.

Now, is it not much more probable that these inconsiderable quantities of azot, which in the last experiment amounted to no more than $\frac{1}{17}$ part by weight of the whole gas employed, pre-existed in the gases before the combustion began, though their extreme minuteness prevented them from being discovered, than that they were formed during the experiment: a supposition

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Objections to the composition of water examined.

Water. position which is directly contradicted by a great number of well ascertained facts.

As to the carbonic acid gas, which in the second experiment amounted to $\frac{1}{27}$ th of the gases employed, it was evidently derived from the manganese, which almost constantly contains it. And when carbonic acid is once mixed with oxygen, it is difficult to separate it by means of lime-water, except a large quantity be used, as Mr Cavendish has well observed. The reason is, that oxygen gas has the property of dissolving carbonic acid, as Mr Welter has remarked*. Mr le Fevre de Gineau ascertained by experiment, that 1870 cubic inches of oxygen gas, which did not affect lime-water, lost between $\frac{1}{17}$ th and $\frac{1}{10}$ th of its weight when washed in *milk of lime* (B).

In a second experiment, he previously washed the two gases in milk of lime, and the residuum after combustion contained no carbonic acid gas. In a third experiment he washed only the oxygen, and obtained products equally free from carbonic acid. It is certain, then, that the *carbonic acid* is but an accidental mixture. As to the carbonic acid of the third experiment above related, which amounted only to $\frac{1}{17}$ th part of the gases employed, the source of it has been already pointed out.

As to the nitric acid, the quantity of nitre obtained in Mr Lavoisier's experiment was 56 grains; which, according to Mr Kirwan's calculation, contain 30,156 grains of nitric acid; a quantity considerably less than $\frac{1}{10}$ th part of the gases which disappeared. In the second experiment, the nitre obtained amounted to 80,7 grains; which, according to Kirwan, contain 43,456 grains of nitric acid, or less than $\frac{1}{17}$ th part of the gases consumed. Now, as nitric acid is composed of oxygen and azot, both of which were present in the vessel, it is easy to see how it was produced. And that its production is merely accidental, and not necessary, is evident from the last experiment, in which no nitric acid was formed. It has been ascertained, indeed, that the formation of this acid during these experiments is quite arbitrary. It never is formed when the combustion goes on so slowly as to produce but little heat, as Seguin has ascertained †; because oxygen and azot do not combine except at a high temperature. Nor is it formed even at a high temperature, as Mr Cavendish has proved ‡, except there be a deficiency of hydrogen; because hydrogen has a stronger affinity for oxygen than azot has.

The quantity of water obtained in the first experiment was just 30 grains more than the weight of the gases which had disappeared: the water obtained in the second was precisely 30 grains less than the gases consumed: and in the third experiment, the difference was only 16 grains. The quantities of gas operated

upon were large; in all of the experiments several thousand grains, and in one of them above 20 thousand. Now, how is it possible that the water produced should correspond so exactly with the gases consumed (for the differences are so small as not to merit any attention), unless the water had been formed by the combination of these gases?

Dr Priestley, however, who made a great many experiments on this subject, drew from them a very different conclusion; and thought he had proved, that during the combustion the two gases combined, and that the combination was nitric acid. This theory was adopted, or rather it was suggested, by Mr Keir, who has supported it with a great deal of ingenuity*.

Let us examine these experiments of Dr Priestley †, and see whether they warrant the conclusions he has drawn from them. The gases were exploded in vessels of copper. He found that the quantity of water obtained was always less than that of the gases which he had used. He obtained also a considerable quantity of nitric acid. In the experiment made on the largest quantity of the gases, and from which he draws his conclusions, the quantity of liquid obtained amounted to 442 grains. This liquid was examined by Mr Keir. It was of a green colour, 72 grains of brown oxide of copper were deposited in it, and it contained a solution of nitrat of copper (copper combined with nitric acid). Mr Keir analysed this liquor: It consisted of pure water and nitrat of copper; and Mr Keir concluded that the nitric acid formed amounted to $\frac{1}{17}$ th of the oxygen gas employed. Mr Berthollet, however, has shewn that it could not have amounted to more than $\frac{1}{17}$ th part ‡. Let us suppose, however, that it amounted to $\frac{1}{17}$ th. quantity of oxygen and hydrogen gas has disappeared: What has become of them? They have combined, says Dr Priestley, and formed nitric acid. This nitric acid is only $\frac{1}{17}$ th of their weight: Dr Priestley supposes, however, that it contains the whole oxygen and hydrogen that existed in these gases, and that all the rest of the weight of these gases was owing to a quantity of water which they had held in solution. Oxygen gas, then (for we shall neglect the hydrogen, which Dr Priestley was not able to bring into view at all), is composed of one part of oxygen and 19 of water. Where is the proof of this? Dr Priestley informs us, that he ascertained by experiment that half the weight of carbonic acid gas was pure water. Supposing the experiment accurate (c), what can be concluded from it? Surely to bring it forward in proof, that oxygen gas consists of $\frac{1}{17}$ th parts, or almost wholly of water, is downright trifling. It is impossible, therefore, from Dr Priestley's experiments, allowing his suppositions and conjectures their utmost force, to account for the disappearing

(B) Lime mixed with water till it is of the thickness of *milk*, or rather of *cream*.

(C) He informs us that the carbonat of barytes does not yield its carbonic acid by means of heat (this Dr Hope has shewn to be a mistake); but that, when the vapours of water are passed over it, the gas is disengaged: and he determines, by the water missing, how much has combined with the gas. According to him, 60 grains of water enter into the composition of 147 grains of gas. But, besides assigning too small a weight to the gas, he forgot that its temperature was high, and that therefore it was capable of combining with much more water than in its usual state: nor did he ascertain whether more of this water was deposited on the vessels; and yet, by neglecting this precaution, Morveau has shewn, that Mr Kirwan, in a similar experiment, obtained a result nine times greater than it ought to have been. *Encycl. Method. Chim. art. Air.*

* *Ann. de Chim. iii.* 91.

† *Ann. de Chim. ix.* 48.

‡ *Phil. Transf.* 1784.

* Keir's *Dictionary, Art. Nitrous Acid.* † *Phil. Transf.* 1788.

‡ *Ann. de Chim. iii.* 86.

Water. pearing of the two gases, or the appearance of the water, without admitting that this liquid was actually composed of oxygen and hydrogen. If we add to this, that no oxygen gas has hitherto (as far as we know at least) been procured absolutely free from some admixture of azot, and that his oxygen was always procured either from red oxide of lead, or from black oxide of manganese, or red oxide of mercury, all of which substances yield a considerable proportion of azot; that in one experiment, in which he observes that his oxygen was *very pure*, as it had been obtained from red oxide of mercury, Mr Berthollet (D) ascertained, by actually making the experiment, that part of the *very same* oxide which Dr Priestley had employed yielded a gas, $\frac{1}{7}$ d of which was azot*; if we add, that it has been proved beyond the possibility of doubt, and to Dr Priestley's own satisfaction, that nitric acid is composed of oxygen and azot—we shall find it no difficult matter to explain the origin of that acid in Dr Priestley's experiments: and if we recollect that in Seguin's experiment, upon a much larger scale indeed than Dr Priestley's, no nitric acid at all was formed, it will be impossible for us to believe for a moment that the compound formed by oxygen and hydrogen is nitric acid. Thus Dr Priestley's experiments rather confirm than destroy the theory of the composition of water. We obtain from them, however, one curious piece of information, that the presence of copper increases the quantity of nitric acid formed. This curious fact, with a variety of others of a similar nature, will perhaps afterwards claim our attention; but at present we must consider another theory which this phenomenon suggested, and which was first proposed, we believe, by Mr de la Metherie (E).

Had the French chemists, it has been said, employed copper vessels in their experiments, they would have obtained three times the quantity of nitric acid. This acid, therefore, must in their experiments have been decomposed, after having been formed, for want of a base to combine with; and the azot which appeared in the residuum was owing to this decomposition. Hydrogen and oxygen, therefore, do not form water, but azot (F). Let us examine the experiment of Mr Le Fevre by this theory, as the quantity of azot was accurately ascertained. The nitric acid obtained amounted to 43,456 grains; three times that quantity is 130,368 grains, into which 23054 grains of gas were converted; which is impossible. Or even supposing that the decomposition had been going on during the whole experiment, which is directly contrary to Dr Priestley's experiments, and which there is no reason whatever to suppose, but every reason against—still the whole azot amounted only to $\frac{1}{8}$ th of the quantity of gas employed, allowing this gas

to have contained no azot, which was evidently not the case. It appears, then, that this hypothesis, even if it could be admitted, would be totally inadequate to account for the phenomena. But if we were to examine it by Mr Seguin's experiment, its absurdity would be still more glaring. In that experiment the azotic gas amounted to only 19 grains, and the quantity of gas which disappeared was 59+6 grains: so that were the hypothesis true, oxygen and hydrogen gas would consist of one part of oxygen and hydrogen and 312 parts of water; a supposition so enormously absurd, that it is impossible for any person even to advance it.

It is impossible, therefore, for the phenomena which attend the combustion of oxygen and hydrogen gas to be accounted for in any way consistent with common sense, except we suppose that water is formed.

But the experiments above related, conclusive as they appear, are not the only ones by which this important fact has been ascertained. Messrs Van Troostwyk and Dieman, assisted by Mr Cuthbertson, filled a small glass tube, $\frac{1}{4}$ th of an inch in diameter and 12 inches long, with distilled water. One end of this tube was sealed hermetically; but, at the same time, a small gold wire had been passed through it. Another wire passed thro' the open end of the tube, and could be fixed at greater or smaller distances from the first wire. By means of these wires, they made a great number of electrical explosions pass through the water. Bubbles of air appeared at every explosion, and collected at the top of the tube. When electric sparks were passed through this air, it exploded and disappeared almost completely. It must therefore have consisted of a mixture of oxygen and hydrogen gas, and this gas must have been formed by the decomposition of the water: for they had taken care to deprive the water before hand of all its air, and they used every precaution to prevent the access of atmospheric air; and, besides, the quantity of gas produced did not diminish, but rather increased, by continuing to operate a number of times upon the same water, which could not have been the case had it been merely air dissolved in water: nor would atmospheric air have exploded and left only a very small residuum, not more than $\frac{1}{80}$ th part. They had taken care also to prove that the electric spark did not contribute to form hydrogen gas; for on passing it through sulphuric and nitric acids, the product was not hydrogen, but oxygen gas*.

These experiments have been since repeated by Dr Pearson, assisted by Mr Cuthbertson. He produced, by means of electricity, quantities of gas from water, amounting to 56,5488 cubes of $\frac{1}{15}$ th of an inch each; on nitrous gas being added to which, it suffered a diminution

(D) Mr Berthollet had supplied Dr Priestley with the oxide. He had received two ounces of it from Mr Le Blanc, one of which he sent to Dr Priestley, and the other he reserved.

(E) Another favourite theory of La Metherie was, that gases themselves are destitute of gravity, and that they owe their whole weight to the water with which they are combined: that during combustion the water of the two gases is deposited; and that the gases themselves escape through the vessel and are lost. He complains bitterly that this theory had never been noticed by his antagonists; as if it were necessary to refute a hypothesis which is not supported by any proof whatever, and as if it had not been proved that oxygen increases the weight of metals, and consequently possesses gravity.

(F) This, as has been formerly explained, was the original opinion of Dr Priestley; to which, though he does not explain himself fully, he evidently still adheres. There is then no difference between his theory and this, except what relates to the decomposition of the nitric acid.

Alcohol. nution of bulk, and nitrous acid appeared to have been formed: It must therefore have contained oxygen gas. When oxygen gas was added to the remainder, and an electric spark passed through it, a diminution took place precisely as when oxygen and hydrogen gas are mixed: It must therefore have contained hydrogen. When an electric spark was passed through the gas thus produced from water, the gas disappeared, being no doubt converted into water*.

* Nicholson's Journal, i. 242.

Such are the proofs by which the compound nature of water is ascertained; and we do not believe that any physical fact whatever can be produced which is supported by more complete evidence.

But what becomes of the caloric which was previously combined with these gases? It passes through the vessel and is lost, and its weight is too inconsiderable to make any sensible variation in the quantity of the product. If we were to judge from analogy, we would conclude, that the oxygen and hydrogen, while in the state of gas, are probably somewhat lighter than after they are condensed into water; but the difference, if it exists, can scarcely be sensible.

348
Combination and affinity of water.

Water is capable of combining with a vast number of substances: all bodies, indeed, which are soluble in water form a chemical union with it.

Its affinity for other bodies is doubtless various, tho' we have no method of ascertaining this difference, except in those bodies which have no affinity, or but a very small affinity, for each other; and it is only in a few even of these that this difference can be ascertained. If muriat of barytes be poured into lime-water, the lime is precipitated, owing, no doubt, to the superior affinity of the muriat for water. Several very curious instances of the affinity of different salts for water have been mentioned by Mr Quatremere Dijonval. When the solutions of nitrat of lime and nitrat of magnesia in water are mixed together, the nitrat of magnesia is precipitated. Muriat of magnesia is also precipitated by muriat of lime, and sulphat of magnesia by sulphat of lime: so that it would seem that the salts which have magnesia for their basis, have a less affinity for water than those whose basis is lime †.

† Journ. de Phys. xvii.

Water has the property of dissolving oxygen gas. If a quantity of common air be confined for some time above water, the whole of the oxygen is absorbed, and nothing but the azotic gas remains. This fact was first observed by Mr Scheele.

CHAP. II. OF ALCOHOL.

349
Discovery of alcohol.

WINE has been known from the earliest ages. The Scriptures inform us, that Noah planted a vineyard and drank wine; and the heathen writers are unanimous in ascribing the invention of this liquor to their earliest kings and heroes. Beer, too, seems to have been discovered at a very remote period. It was in common use in Egypt in the time of Herodotus †. Tacitus informs us, that it was the drink of the Germans §. Whether the ancients had any method of procuring ardent spirits from these or any other liquors, does not appear. The Greeks and Romans seem to have been ignorant of ardent spirits altogether, at least we can discover no traces of any such liquor in their writings. But among the northern nations of Europe, intoxicating liquors were in use from the earliest ages. Whether these li-

† Lib. ii. n. 77.
§ De Morib. Germ. ch. xxiii.

quors resembled the beer of the Germans, we do not know. It is certain, at least, that the method of procuring ardent spirits by distillation was known in the dark ages; and it is more than probable that it was practised in the north of Europe much earlier. They are mentioned expressly by Thaddæus, Villanovanus, and Lully*.

Alcohol. * Berg. 4th. art. ii. 4. 350
Method of procuring

Ardent spirits, such as brandy, for instance, rum, and whisky, consist almost entirely of three ingredients, water, alcohol or spirit of wine, to which they owe their strength, and a small quantity of a peculiar oil, to which they owe their flavour.

The alcohol may be separated from the water by the following process. Into the whisky or other ardent spirit a quantity of potash is to be put, which has just immediately before been exposed for about half an hour in a crucible to a red heat, in order to deprive it of moisture. Potash in this state has a strong attraction for water; it accordingly combines with the water of the spirit, and the solution of potash thus formed sinks to the bottom of the vessel, and the alcohol, which is lighter, swims over it, and may easily be decanted off; or, what is perhaps better, the solution of potash may be drawn off from below it by means of a stop-cock placed at the bottom of the vessel. It is impossible to fix the quantity of potash which ought to be used, because that must depend entirely on the strength of the spirit; but it is of no consequence though the potash employed be a little more than enough. The alcohol thus obtained contains a little potash dissolved, which may be separated by distilling it in a water bath with a very small heat. The alcohol passes over, and leaves the potash behind. It is proper not to distil to dryness. This process is first mentioned by Lully. Alcohol may be obtained in the same manner from wine and from beer; which liquids owe their strength entirely to the quantity of that substance which they contain.

Alcohol is a transparent liquor, colourless like water, its proper-³⁵¹ of a pleasant smell, and a strong penetrating agreeableness of taste.

It is exceedingly fluid, and has never been frozen, though it has been exposed to a cold so great that the thermometer stood at -69° †.

† At Hudson's Bay.

Its specific gravity when pure is about 0,800.

It is exceedingly volatile, boiling at the temperature of 176° ; in which heat it assumes the form of an elastic fluid, capable of resisting the pressure of the atmosphere, but which condenses again into alcohol when that temperature is reduced. In a vacuum it boils at 56° , and exhibits the same phenomena: so that were it not for the pressure of the atmosphere, alcohol would always exist in the form of an elastic fluid, as transparent and invisible as common air. This subject was first examined with attention by Mr Lavoisier ‡. The fact, however, had been known long before.

‡ Journ. de Phys. 1785.

Alcohol has a strong affinity for water, and is miscible with it in all proportions. The specific gravity of all the different mixtures, in every proportion, and in all the different degrees of temperature, from 32° to 100° , has been lately ascertained with great accuracy by Sir Charles Blagden and Mr Gilpin. But as a very full account of these interesting experiments has been given in the Encyclopædia in the article *SPIRITUOUS LIQUORS*, we do not think ourselves at liberty to repeat it here.

If alcohol be set on fire, it burns all away with a blue flame without leaving any residuum. Boerhaave observed,

Alcohol. observed, that when the vapour which escapes during this combustion is collected in proper vessels, it is found to consist of nothing but water. Junker had made the same remark: and Dr Black suspected, from his own observations, that the quantity of water obtained, if properly collected, exceeded the weight of the alcohol consumed. This observation was confirmed by Lavoisier; who found that the water produced during the combustion of alcohol exceeded the alcohol consumed by about $\frac{1}{4}$ th part*.

* Mem. Par. 1781. P. 493. Different opinions were entertained by chemists about the nature of alcohol. Stahl thought that it was composed of a very light oil, united by means of an acid to a quantity of water. According to Junker, it was composed of phlogiston, combined with water by means of an acid. Cartheuser, on the other hand, affirmed, that it contained no acid, and that it was nothing else than pure phlogiston and water. But these hypotheses were mere assertions supported by no proof whatever. Lavoisier was the first who attempted to analyse it.

353 Lavoisier's analysis. He set fire to a quantity of alcohol in close vessels, by means of the following apparatus: BCDE (fig. 6.) is a vessel of marble filled with mercury. A is a strong glass vessel placed over it, filled with common air, and capable of containing about 15 pints (French). Into this vessel is put the lamp R filled with alcohol, the weight of which has been exactly determined. On the wick of the lamp is put a small particle of phosphorus. The mercury is drawn up by suction to the height IH. This glass communicates by means of the pipe LK with another glass vessel S filled with oxygen gas, and placed over a vessel of water T. This communication may be shut up at pleasure by means of the stop-cock M.

Things being thus disposed, a crooked red-hot iron wire is thrust up through the mercury, and made to touch the phosphorus. This instantly kindles the wick, and the alcohol burns. As soon as the flame begins to grow dim, the stop-cock is turned, and a communication opened between the vessels S and A; a quantity of oxygen gas rushes in, and restores the brightness of the flame. By repeating this occasionally, the alcohol may be kept burning for some time. It goes out, however, at last, notwithstanding the admission of oxygen gas.

The result of this experiment, which Mr Lavoisier repeated a great number of times, was as follows:

The quantity of alcohol consumed amounted to 76,7083 grains troy.

The oxygen gas consumed amounted to 266,82 cubic inches, and weighed 90,506 grains troy.

The whole weight of the substances consumed, therefore, amounted to 167,2143 grains.

After the combustion, there were found in the glass vessel 115,41 cubic inches of carbonic acid gas, the weight of which was 78,1192 grains troy. There was likewise found a considerable quantity of water in the vessel, but it was not possible to collect and weigh it. Mr Lavoisier, however, estimated its weight at 89,0951 grains; as he concluded, with reason, that the whole of the substances employed were still in the vessel. Now the whole contents of the vessel consisted of carbonic acid gas and water; therefore the carbonic acid gas and water together must be equal to the oxygen gas and alcohol which had been consumed.

But 78,1192 grains of carbonic acid gas contain, according to Mr Lavoisier's calculation †, 55,279 grains of oxygen: 90,506 grains, however, of oxygen gas had

disappeared; therefore 35,227 grains must have been employed in forming water. Alcohol.

35,227 grains of oxygen gas require, in order to form water, 6,038 grains of hydrogen gas; and the quantity of water formed by this combination is 41,265 grains. But there were found 89,095 grains of water in the glass vessel; therefore 47,83 grains of water must have existed ready formed in the alcohol.

It follows from all these data, that the 76,7083 grains of alcohol, consumed during the combustion, were composed of

22,840 Carbon,
6,038 Hydrogen,
47,830 Water.

76,7*

* Mem. Par. 1784.

Such were the consequences which Mr Lavoisier drew from his analysis. He acknowledged, however, that there were two sources of uncertainty, which rendered his conclusions not altogether to be depended upon. The first was, that he had no method of determining the quantity of alcohol consumed, except by the difference of weight in the lamp before and after combustion; and that therefore a quantity might have evaporated without combustion, which, however, would be taken into the sum of the alcohol consumed. But this error could not have been great; for if a considerable quantity of alcohol had existed in the state of vapour in the vessel, an explosion would certainly have taken place. The other source of error was, that the quantity of water was not known by actual weight, but by calculation.

To this we may add, that Mr Lavoisier was not warranted to conclude from his experiment, that the water found in the vessel, which had not been formed by the oxygen gas used, had existed in the alcohol in the state of water: he was intitled to conclude from his data, that the ingredients of that water existed in the alcohol before combustion; but not that they were actually combined in the state of water, because that combination might have taken place, and in all probability did partly take place, during the combustion. It follows, therefore, from Mr Lavoisier's experiments, that alcohol, supposing he used it perfectly pure, which is not probable, is composed of

0,2988 parts carbon,
0,1840 parts hydrogen,
0,5172 parts oxygen.

1,0000

But it gives us no information whatever of the manner in which these ingredients are combined. That alcohol contains oxygen, has been proved by a very ingenious set of experiments performed by Messrs Fourcroy and Vauquelin. When equal parts of alcohol and sulphuric acid are mixed together, a quantity of caloric is disengaged, sufficient to elevate the temperature of the mixture to 190°. Bubbles of air are emitted, the liquor becomes turbid, assumes an opal colour, and at the end of a few days a deep red. When examined, the sulphuric acid is found to have suffered no change; but the alcohol is decomposed, partly converted into water and partly into ether, a substance which we shall describe immediately. Now, it is evident that the alcohol could not have been converted into water unless it had contained oxygen*.

When equal parts of sulphuric acid and alcohol are mixed together and heat applied, the mixture boils at

208°,

352 Opinions concerning its composition.

* Mem. Par. 1781. P. 493.

353 Lavoisier's analysis.

† Mem. Par. 1781.

* Nichol. son's Journal, i. 394.

Alcohol.

208°, and a liquid equal to half the weight of the alcohol comes over into the receiver. This liquid is *ether*.

355
Ether.

Ether is obscurely hinted at in some of the older chemical authors, but little attention was paid to it till a paper appeared in the Philosophical Transactions for 1730, written by a German, who called himself *Frobenius* (G), containing a number of experiments on it. In this paper it first received the name of *ether*.

356
Its properties.

Ether is limpid and colourless, of a very fragrant smell, and a hot pungent taste. Its specific gravity is 0,7394. It is exceedingly volatile, boiling in the open air at 98°, and in a vacuum at -20°. Were it not therefore for the pressure of the atmosphere, it would always exist in a gaseous state. Ether unites with water in the proportion of ten parts of the latter to one of the former*. It is exceedingly inflammable, and, when kindled in the state of vapour, burns with rapidity, or rather explodes, if it be mixed with oxygen gas.

* Count de
Lauraguais.357
Theory of
its forma-
tion.

Chemists entertained various opinions respecting the nature of ether. Macquer supposed that it was merely alcohol deprived by the acid of all its water. But it was generally believed that the acid entered partly into its composition. Since the nature of acids has become better known, a great number of philosophers have supposed that ether is merely alcohol combined with a quantity of oxygen furnished by the acid. The real composition of this singular substance has been lately ascertained by the experiments of Fourcroy and Vauquelin.

“A combination (say they) of two parts of sulphuric acid and one part of alcohol elevates the temperature to 201°, becomes immediately of a deep red colour, which changes to black a few days afterwards, and emits a smell perceptibly ethereal.

“When we carefully observe what happens in the combination of equal parts of alcohol and concentrated sulphuric acid exposed to the action of caloric in a proper apparatus, the following phenomena are seen :

“1. When the temperature is elevated to 208°, the fluid boils, and emits a vapour which becomes condensed by cold into a colourless, light, and odorous liquor, which from its properties has received the name of *ether*. If the operation be properly conducted, no permanent gas is disengaged until about half the alcohol has passed over in the form of ether. Until this period there passes absolutely nothing but ether and a small portion of water, without mixture of sulphurous or of carbonic acid.

“2. If the receiver be changed as soon as the sulphurous acid manifests itself, it is observed that no more ether is formed, but the sweet oil of wine, water, and acetous acid, without the disengagement hitherto of a single bubble of carbonic acid gas. When the sulphuric acid constitutes about four-fifths of the mass which remains in the retort, an inflammable gas is disengaged, which has the smell of ether, and burns with a white oily flame. This is what the Dutch chemists have called *carbonated hydrogen gas*, or *olefant gas*, because when mixed with the oxy-muriatic acid it forms oil. At this period the temperature of the fluid contained in the retort is elevated to 230° or 234°.

“3. When the sweet oil of wine ceases to flow, if the receiver be again changed, it is found that nothing more passes but sulphurous acid, water, carbonic acid gas; and that the residuum in the retort is a black mass, consisting for the most part of sulphuric acid thickened by carbon.

“The series of phenomena here exposed will justify the following general inductions :

Alcohol.

“1. A small quantity of ether is formed spontaneously, and without the assistance of heat, by the combination of two parts of concentrated sulphuric acid and one part of alcohol.

“2. As soon as ether is formed, there is a production of water at the same time; and while the first of these compositions takes place, the sulphuric acid undergoes no change in its intimate nature.

“3. As soon as the sulphurous acid appears, no more ether is formed, or at least very little; but then there passes the sweet oil of wine, together with water and acetous acid.

“4. The sweet oil of wine having ceased to come over, nothing further is obtained but the sulphurous and carbonic acids, and at last sulphur, if the distillation be carried to dryness.

“The operation of ether is therefore naturally divided into three periods: the first, in which a small quantity of ether and water are formed without the assistance of heat; the second, in which the whole of the ether which can be obtained is disengaged without the accompaniment of sulphurous acid; and the third, in which the sweet oil of wine, the acetous acid, the sulphurous acid, and the carbonic acid, are afforded. The three stages have no circumstance common to all, but the continual formation of water, which takes place during the whole of the operation.

“The ether which is formed without the assistance of caloric, and the carbon which is separated without decomposition of the sulphuric acid, prove that this acid acts on alcohol in a manner totally different from what has hitherto been supposed. It cannot, in fact, be affirmed, that the acid is altered by the carbon, because daily experience shews that no sensible attraction takes place between these two bodies in the cold; neither can it be affected by the hydrogen; for in that case sulphurous acid would have been formed, of which it is known that no trace is exhibited during this first period. We must therefore have recourse to another species of action, namely, the powerful attraction exercised by the sulphuric acid upon water. It is this which determines the union of the principles which exist in the alcohol, and with which the concentrated acid is in contact: but this action is very limited if the acid be small in quantity; for an equation of affinity is soon established, the effect of which is to maintain the mixture in a state of repose.

“Since it is proved that ether is formed in the cold by the mixture of any quantities of alcohol and sulphuric acid, it is evident that a mass of alcohol might be completely changed into ether and vegetable acid by using a sufficient abundance of sulphuric acid. It is equally evident that the sulphuric acid would not by this means undergo any other change than that of being diluted with a certain quantity of water. This observation proves that alcohol contains oxygen, because water cannot exist without this principle, which must be afforded by the alcohol only, since the sulphuric acid suffers no decomposition.

“We must not, however, imagine, from these facts, that ether is alcohol minus oxygen and hydrogen. Its properties alone would contradict this; for a quantity of carbon proportionally greater than that of the hydrogen

(G) The name was supposed to have been feigned.

Alcohol hydrogen is at the same time separated. It may, in fact, be conceived that the oxygen, which in this case combines with the hydrogen to form water, not only saturates that hydrogen in the alcohol, but likewise the carbon. So that, instead of considering ether as alcohol minus hydrogen and oxygen, we must, by keeping an account of the precipitated carbon and the small quantity of hydrogen contained in the water which is formed, regard it as alcohol plus hydrogen and oxygen.

"The foregoing are the effects produced by a combination of alcohol and sulphuric acid, spontaneously produced without foreign heat. Let us, in the next place, observe how this combination is effected when caloric is added. The phenomena are then very different, tho' some of the results are the same.

"In the first place, we must observe, that a combination of sulphuric acid and alcohol in equal parts does not boil at less than 207 degrees of temperature, while that of alcohol alone boils at 176. Now since ebullition does not take place till the higher temperature, it is clear that the alcohol is retained by the affinity of the sulphuric acid, which fixes it more considerably. Let us also consider that organic bodies, or their immediate products, exposed to a lively brisk heat, without the possibility of escaping speedily enough from its action, suffer a partial or total decomposition, according to the degree of temperature. Alcohol undergoes this last alteration when passed through an ignited tube of porcelain. By this sudden decomposition it is converted into water, carbonic acid, and carbon. The reason, therefore, why alcohol is not decomposed when it is submitted alone to heat in the ordinary apparatus for distillation, is, that the temperature at which it rises in vapours is not capable of effecting the separation of its principles; but when it is fixed by the sulphuric acid or any other body, the elevated temperature it undergoes, without the possibility of disengagement from its combination, is sufficient to effect a commencement of decomposition, in which ether and water are formed, and carbon is deposited. Nothing more therefore happens to the alcohol in these circumstances than what takes place in the distillation of every other vegetable matter in which water, oil, acid, and coal, are afforded.

"Hence it may be conceived that the nature of the products of the decomposition of alcohol must vary according to the different degrees of heat; and this explains why at a certain period no more ether is formed but the sweet oil of wine and acetous acid. In fact, when the greatest quantity of the alcohol has been changed into ether, the mixture becomes more dense, and the heat which it acquires previous to ebullition is more considerable. The affinity of the acid for alcohol being increased, the principles of this acid become separated; so that, on the one hand, its oxygen seizes the hydrogen, and forms much water, which is gradually volatilized; while, on the other, the ether retaining a

greater quantity of carbon, with which at that temperature it can rise, affords the sweet oil of wine. This last ought therefore to be considered as an ether containing an extraordinary portion of carbon, which gives it more density, less volatility, and a lemon yellow colour.

"During the formation of the sweet oil of wine, the quantity of carbon which is precipitated is no longer in the same proportion as during the formation of ether.

"What we have here stated concerning the manner in which ether is formed by the simultaneous action of the sulphuric acid and heat, appears so conformable to truth, that nearly the same effects may be produced by a caustic fixed alkali. In this case also a kind of ether and a sweet oil of wine are volatilized, and coal is precipitated. It is therefore only by fixing the alcohol that the sulphuric acid permits the caloric to operate a sort of decomposition. It may also be urged as a proof of this assertion, that the sulphuric acid, which has served to make ether as far as the period at which the sweet oil of wine begins to appear, is capable of saturating the same quantity of alkali as before its mixture with the alcohol".

Ether may also be obtained by means of several other acids. The different liquids thus formed are distinguished by prefixing the name of the acid used in the process. Thus the ether above described is called *sulphuric ether*; that obtained by means of nitric acid, *nitric ether*, and so on. There are several minute shades of difference between these various ethers, which have not yet been properly inquired into.

Alcohol is capable of dissolving a great many bodies. A considerable number of these, with the quantities soluble in alcohol, is exhibited in the following tables.

I. Substances dissolved in large Quantities.

Names of the Substances.	Temperature.	240 parts of alcohol dissolve
Nitrat of cobalt -	54,5°	240 parts
copper -	54,5	240
alumina -	54,5	240
magnesia -	180,5	694
Muriat of zinc -	54,5	240
alumina -	54,5	240
magnesia -	180,5	1313
iron -	180,5	240
copper -	180,5	240
Acetite of lead -	113	
copper †		
Benzoic acid - - -	135,5	
Sulphat of magnesia		
Nitrat of zinc decomposed		
iron decomposed		
bismuth decomposed		

* Nicholson's Journ. i. 391.

338
Substances soluble in alcohol.

† Withering, Phil. Trans. lxxii. 336.

II. *Substances dissolved in small Quantities.*

Names of the Substances.	240 parts of alcohol at the boiling temperature dissolve
Muriat of lime - - -	240 parts
Nitrat of ammonia - - -	214
Oxy-muriat of mercury - - -	212
Succinic acid - - -	177
Acetite of foda - - -	112
Nitrat of silver - - -	100
Refined sugar - - -	59
Boracic acid - - -	48
Nitrat of foda - - -	23
Acetite of copper - - -	18
Muriat of ammonia - - -	17
Arfeniat of potafs - - -	9
Acidulated oxalat of potafs - - -	7
Nitrat of potafs - - -	5
Muriat of potafs - - -	5
Arfeniat of foda - - -	4
Barytes	
Strontites	
White oxide of arfenic - - -	3
Tartrat of potafs - - -	1
Phosphorus	
Nitrat of lead *	
lime *	
Muriat of mercury †	
Carbonat of ammonia *	

* *Withering, Phil. Trans. lxxii. 336.*
 † *Macquer, ibid.*

III. *Substances insoluble with Alcohol.*

Sugar of milk,	Sulphat of foda,
Borax,	magnesia,
Tartar,	Sulphite of foda,
Alum,	Tartrate of foda and
Sulphat of ammonia,	potafs,
lime,	Phosphoric acid,
barytes †,	Nitrat of lead,
iron (green),	mercury,
copper,	Muriat of lead,
silver,	silver †,
mercury,	Common salt,
zinc,	Carbonat of potafs,
potafs,	foda.

† *Withering, ibid.*

§ *Macquer, ibid.*

These have been chiefly borrowed from tables which Mr de Morveau published in the *Journal de Physique* July 1785, and which were drawn up for the most part from the experiments described in Wenzel's Treatise on Affinities.

The affinities of alcohol are very imperfectly known. Those stated by Bergman are as follows:

Water,
 Ether,
 Volatile oil,
 Sulphurets of alkalies.

CHAP. III. *Of OILS.*

360
 Discovery of oil.

OIL, which is of such extensive utility in the arts, was known at a very remote period. It is mentioned

in Genesis, and during the time of Abraham was even used in lamps*. The olive was very early cultivated, and oil extracted from it in Egypt. Cecrops brought it from Sais, a town in Lower Egypt, where it had been cultivated from time immemorial, and taught the Athenians to extract oil from it. In this manner the use of oil became known in Europe †. But the Greeks seem to have been ignorant of the method of procuring light by means of lamps till after the siege of Troy; at least Homer never mentions them, and constantly describes his heroes as lighted by torches of wood.

Oils are divided into two classes, *Fixed* and *Volatile*; each of which is distinguished by peculiar properties.

I. The *FIXED OILS*, called also *fat* or *expressed* oils, are numerous, and are obtained, partly from animals and partly from vegetables, by simple expression. As instances, we shall mention whale oil or train oil, obtained from the blubber of the whale; olive oil, obtained from the fruit of the olive; lintseed oil and almond oil, obtained from lintseed and almond kernels. Fixed oils may also be obtained from poppy seeds, hemp seeds, beech mast, and many other vegetable substances.

All these oils differ from each other in several particulars, but they also possess many particulars in common. Whether the oily principle in all the fixed oils is the same, and whether they owe their differences to accidental ingredients, is not yet completely ascertained, as no proper analysis has hitherto been made; but it is exceedingly probable, as all the oils hitherto tried have been found to yield the same products. In the present state of our knowledge, it would be useless to give a particular description of all the fixed oils, as the differences between them have not even been accurately ascertained. We shall content ourselves, therefore, with giving the characters which distinguish fixed oils in general, and an analysis of one oil, by way of specimen.

Fixed oils are insoluble in alcohol, which distinguishes them from volatile oils. They are also insoluble in water.

They have an unctuous feel, are transparent while fluid, are destitute of smell, and have a mild insipid kind of taste.

They are all susceptible of becoming solid by exposure to a sufficient degree of cold. Olive oil and almond oil freeze at $10\frac{1}{2}$ degrees †.

They are capable of being converted into vapour by heat; but require for that purpose a temperature considerably superior to that of boiling water. Olive oil boils at 600° , and most of the fixed oils hitherto tried require nearly the same degree of heat.

When in the state of vapour they take fire on the approach of an ignited body, and burn with a yellowish white flame. It is upon this principle that candles and lamps burn. The tallow or oil is first converted into the state of vapour in the wick; it then takes fire, and supplies a sufficient quantity of heat to convert more oil into vapour; and this process goes on while any oil remains. The wick is necessary to present a sufficiently small quantity of oil at once for the heat to act upon. If the heat were sufficiently great to keep the whole oil at the temperature of 600° , no wick would be necessary, as is obvious from oil catching fire spontaneously when it has been raised to that temperature.

Mr Lavoisier analysed olive oil by burning it in precisely the same apparatus as that which he employed for analysing alcohol.

The

Oils.

The quantity of oil consumed amounted to 15,79 grains troy.

The quantity of oxygen gas amounted to 50,86 gr. troy. The whole amount therefore of the substances consumed during the combustion is 66,65 grains troy.

The carbonic acid obtained amounted to 44,50 gr. There was also a considerable quantity of water, the weight of which could not be accurately ascertained: but as the whole of the substances consumed were converted into carbonic acid gas and water, it is evident that if the weight of the carbonic acid be subtracted from the weight of these substances, there must remain precisely the weight of the water. Mr Lavoisier accordingly concluded, by calculation, that the weight of the water was 22,15 grains. Now the quantity of oxygen in 44,50 grains of carbonic acid gas is 32,04 grains, and the oxygen in 22,15 grains of water is 18,82 grains; both of which taken together amount to 50,86 grains, precisely the weight of the oxygen gas employed. There does not appear therefore to be any oxygen in olive oil.

The quantity of carbon in 44,50 grains of carbonic acid gas is 12,47 grains; and the quantity of hydrogen in 22,15 grains of water is 3,32 grains; both of which, when taken together, amount to 15,79 grains, which is the weight of the oil consumed.

It follows, therefore, from this analysis, that 15,79 grains of olive oil are composed of

12,47 Carbon,
3,32 Hydrogen.

Olive oil therefore is composed of about

79 Carbon,
21 Hydrogen.

100*

* Mem. Par. 1784. and Four. de Phys. for 1787, July.

In what manner these substances are combined, cannot be learned from this analysis. Whether they combine directly, and saturate each other in that proportion, as is most probable - or whether the hydrogen is combined previously with a part of the carbon, and that compound combining with a certain quantity of carbon, forms oil, is altogether uncertain. Yet these questions are of the utmost importance; and till the method of solving them be discovered, we never can acquire any precise ideas about the constituent parts of a great number of substances, which, though formed ultimately of the same ingredients, differ very much in their properties from one another; as wax and oil; alcohol, sugar, and ether.

364 Rancidity.

When fixed oils are exposed to the atmosphere, they become thick, acquire a brown colour, and a peculiarly unpleasant smell: they are then said to be rancid. When oil is poured upon water, so as to form a thin layer on its surface, and is in that manner exposed to the atmosphere, these changes are produced much sooner, the oil becomes thicker, and assumes an appearance very much resembling wax. Berthollet, who first examined these phenomena with attention, ascribed them to the action of light: but Sennebler observed, that no such change was produced on the oil though ever so long exposed to the light, provided atmospheric air

was excluded; but that it took place on the admission of oxygen gas, whether the oil was exposed to the light or not*. It cannot be doubted, then, that it is owing to the combination of oxygen. All substances that are capable of supplying that principle, the metallic oxides for instance, and several of the acids, produce the same effect upon oils; and it is a known fact, that oil is capable of reducing many of the metallic oxides to the metallic state, and consequently that it has a stronger affinity for oxygen.

Oils. * Ann. de Chim. xi. 89.

Mr Chaptal has supposed that oils become rancid merely because they contain a quantity of mucilage, with which the oxygen combines; and that when oxygen combines with fixed oils, it produces a different effect, converting them into what is called *drying oils*.

It is certain that oils contain a quantity of mucilage; but some change is evidently produced on the oils themselves by rancidity; for no agitation in water is capable of restoring them to their former state, although water deprives them of their mucilage. *Drying oils*, so called because they are capable of *drying* completely when spread out, a property which renders them useful in painting, seem, as Sennebler observes, to be completely deprived of mucilage; for, in order to render an oil drying, it must be boiled, which evaporates or decomposes all the mucilage: they seem also to lose part of their hydrogen †.

365 Drying oils.

Fixed oils are capable of dissolving sulphur at their boiling temperature. The solution is very fetid, owing to a partial decomposition of the oil. Hydrogen gas flies off, having a quantity of sulphur dissolved in it. When the solution cools, the sulphur crystallizes.

† Berthollet. 366 Fixed oils dissolve sulphur.

Fixed oils dissolve phosphorus. The solution is luminous, from the slow combustion of the phosphorus.

367 And phosphorus.

Fixed oils are capable of combining with many of the metallic oxides. The compounds are called *metallic soaps*. Several of the oxides are decomposed by being boiled in oils.

Fixed oils combine also with the alkaline earths and with alumina. The compounds are called *earthy soaps*.

The affinities of the oils are as follows:

Lime,	Nitric acid,
Barytes,	Muriatic,
Fixed alkalies,	Sulphurous,
Magnesia,	Sulphuric,
Ammonia,	Acetous,
Oxide of mercury,	Sulphur,
Other metallic oxides (H),	Phosphorus (I).
Alumina.	

368 Their affinities.

II. VOLATILE OILS, called also *essential oils*, are all obtained from vegetables. They have a strong aromatic smell, and a pungent acrid taste. They are so volatile that they may be distilled by the heat of boiling water. They are soluble in alcohol, but not in water. They evaporate on the application of heat, without leaving any stain behind them, which is not the case with the fixed oils. By this test, accordingly, it is easy to discover whether they have been adulterated with any of the fixed oils. Let a drop of the volatile oil fall upon a sheet of writing paper, and then apply a gentle heat

369 Volatile oils.

P p 2

(H) Their order not well ascertained.

(I) The first column was ascertained by Berthollet. The last is to be considered as unconnected with the first. On account of the affinity of these two classes of bodies for each other, it has not been possible to discover which of them has the greatest affinity for oil.

Alkalies. heat to it. If it evaporates without leaving any stain upon the paper, the oil is pure; but if it leaves a stain, it has been contaminated with some fixed oil or other.

Volatile oils are very numerous, and differ from one another, in fluidity and weight, in their freezing point, and in several other particulars. Little attention has been paid to the greatest part of them, because few of them have been found of any use. The principal quality for which they are valued is their odour. Some of them are obtained by expression, as oil of bergamot, lemons, oranges; others by distillation, as oil of peppermint, thyme, lavender, &c. It would be useless, even if it were possible, to give a particular description of all the volatile oils.

370
Their properties.

They are more inflammable than the fixed oils; a quality which they owe to their volatility. As far as experiments have hitherto been made, they seem to consist of carbon and hydrogen; but nothing is known concerning the proportions of these ingredients. They thicken when exposed to the air, probably by combining with oxygen, and form *resins* (κ).

When exposed to cold, or when kept for a long time, some of them deposit crystals resembling the acid of benzoin (λ).

They dissolve sulphur, and form what have been called *balsams of sulphur*.

They are capable of combining with most of the substances that unite with fixed oils. Their affinities, which certainly differ from those of fixed oils, have not yet been properly ascertained.

CHAP. IV. Of ALKALIES.

371
Properties of alkalies.

SUBSTANCES possessed of the following properties are called *alkalies*:

1. Incombustible.
2. Capable of converting vegetable blues to a green.
3. A hot caustic taste.
4. Very soluble in water, even when combined with carbonic acid.

There are three alkalies, *potafs*, *soda*, and *ammonia*. The two first are called *fixed* alkalies, because a very violent heat is necessary to volatilize them; the last is called *volatile* alkali, because it very easily assumes a gaseous form, and is consequently dissipated by a very moderate degree of heat.

SECT. I. Of Potafs.

372
Method of procuring potafs.

If a sufficient quantity of wood be burnt to ashes, and these ashes be afterwards washed repeatedly with water till it comes off free from any taste, and if this liquid be filtrated and evaporated to dryness, the substance which remains behind is *potafs*; not, however, in a state of purity, for it is contaminated with several other substances; but sufficiently pure to exhibit many

of its properties. In this state, it occurs in commerce under the name of *potafs*. It may be purified considerably, by putting it in a crucible, keeping it red hot for some time; then dissolving it in water, filtrating it, and evaporating it again to dryness. By the following method it may be obtained nearly pure: Mix together equal quantities of nitre and carbon, and put them by little and little into a red hot crucible. They burn with a vivid flame, and leave behind them a quantity of potafs. This is to be dissolved in water, filtrated, and evaporated to dryness. Or potafs may be obtained by burning tartar wrapt up in brown paper and placed in a crucible (μ).

Alkalies.

The potafs procured by these last processes is exceedingly white; it is not, however, quite pure; for it is combined with a substance which blunts all its properties considerably. This substance is carbonic acid gas; from which it may be separated by dissolving it, and mixing with it an equal quantity of lime made into a paste with water. The lime has a greater affinity for carbonic acid gas, and therefore combines with it; and the pure potafs remains dissolved in the water, and may be separated from the lime by filtrating the mixture. This process, however, must be performed in close vessels; for there is a little carbonic acid gas in the atmosphere, which would again combine with the potafs if it were allowed to stand exposed to the air.

It is then to be evaporated till a thick pellicle appears on its surface, and afterwards allowed to cool; and all the crystals which have formed are to be separated, for they consist of foreign salts. The evaporation is then to be continued in an iron pot; and, during the process, the pellicle which forms on the surface is to be carefully taken off with an iron skimmer. When no more pellicle appears, and when the matter ceases to boil, it is to be taken off the fire, and must be constantly agitated while cooling with an iron spatula. It is then to be dissolved in double its own weight of cold water. This solution is to be filtered and evaporated in a glass retort till it begin to deposit regular crystals. If the mass consolidates ever so little by cooling, a small quantity of water is to be added, and it must be heated again. When a sufficient number of crystals have been formed, the liquor which swims over them, and which has assumed a very brown colour, must be decanted off, and kept in a well-closed bottle till the brown matter has subsided, and then it may be evaporated as before, and more crystals obtained. The crystals may then be dissolved in pure water. By this process, which was invented by Mr Lowitz of Peterburgh*, potafs may be obtained in a state of the greatest purity. The shape of its crystals is very different, according to the way in which they have been produced. When allowed to form in the cold, they are octahedrons in groups, and contain 0,43 of water: When formed by evaporation

* *Nicollson*, 164.

(κ) Resins are concrete vegetable juices; the distinguishing property of which is insolubility in water and solubility in alcohol. *Common resin*, or *rosin*, from which they derive their name, is one of them; and sealing wax consists almost entirely of another.

(λ) See a paper by Margueron on this subject, *Ann. de Chim.* xxi. 174.

(μ) That potafs was known to the ancient Gauls and Germans, cannot be doubted, as they were the inventors of soap, which, Pliny informs us, they composed of ashes and tallow. These ashes (for he mentions the ashes of the beech tree particularly) were nothing else but potafs; not, however, in a state of purity. *Plinii*, lib. xviii. c. 51. The *xoviv*, 102, mentioned by Aristophanes and Plato, appears to have been a ley made of the same kind of ashes.

Alkalies. tion on the fire, they assume the figure of very thin transparent blades of extraordinary magnitude, which, by an assemblage of lines crossing each other in prodigious numbers, present an aggregate of cells or cavities, commonly so very close, that the vessel may be inverted without losing one drop of the liquid which it contains †.

* *Nielbofsen*, i. 164. Pure potash is so exceedingly corrosive, that when applied to any part of the body, it destroys it almost instantaneously. On account of this property, it has been called *caustic*, and is often used by surgeons under the name of the *potential cautery*, to open abscesses, and destroy useless or hurtful excrescences.

³⁷³ Black's discovery of the cause of its causticity. As potash is never obtained at first in a state of purity, but always combined with carbonic acid, it was long before chemists understood to what the changes produced upon it by lime were owing. According to some, it was deprived of a quantity of mucilage, in which it had formerly been enveloped; while, according to others, it was rendered more active by being more comminuted. At last, in 1756, Dr Black published the celebrated experiments which we have so often mentioned; in which he proved, by the most ingenious and satisfactory analysis, that the *potash* which the world had considered as a simple substance, was really a compound, consisting of potash and carbonic acid; that lime deprived it of this acid; and that it became more active by becoming more simple.

³⁷⁴ Meyer's theory. While Dr Black was thus occupied in Scotland, Mr Meyer was employed in Germany in the same researches; from which, however, he drew very different conclusions. His *Essays on Lime* appeared in 1764. Pouring into lime-water a solution of potash (*carbonat of potash*), he obtained a precipitate, which he found not to differ from limestone. The alkali had therefore deprived the lime of its causticity and its active properties; and these very properties it had itself acquired. From which he concluded, that the causticity of lime was owing to a particular acid with which it had combined during its calcination. The alkali deprived the lime of this acid, and therefore had a stronger affinity for it. To this acid he gave the name of *acidum pingue* or *causticum*. It was, according to him, a subtle elastic mixt, analogous to sulphur, approaching very nearly to the nature of fire, and actually composed of an acid principle and fire. It was expansible, compressible, volatile, affrignant, capable of penetrating all vessels, and was the cause of causticity in lime, alkalies, and metals. This theory was exceedingly ingenious, and it was supported by a vast number of new and important facts. But notwithstanding the reputation and acknowledged genius and merit of its author, it never gained many followers; because the true theory of causticity, which had been already published by Dr Black, soon became known on the continent; and, notwithstanding some opposition at first, soon carried conviction into every unprejudiced mind. Even Mr Meyer himself readily acknowledged its truth and importance, though he did not at first, on that account, give up his own theory.

When potash is exposed to the action of fire, it first becomes soft, and melts into a transparent liquid at the commencement of ignition.

When exposed to the air, it attracts moisture very fast, and is soon converted into a liquid. It attracts, at the same time, carbonic acid gas, for which it has a very strong affinity. It is impossible, then, to keep potash in a state of purity, except in very close vessels.

It unites readily with sulphur, and forms *sulphuret of potash*. This compound may be formed two ways; either by melting the ingredients together, or by boiling them in water, and then filtering the solution. Sulphuret of potash when dry, in which state it is obtained by the first process, is of a brown colour. It is soluble in water, and very soon attracts moisture.

While dry it produces no change upon the air of the atmosphere, as Messrs Dieman, Van Troostwyck, Nieuwland, and Bondt, ascertained by experiment. * *Ann. de Chim.* xiv. 294. But when moistened with water, it very soon absorbs all the oxygen gas which happens to be in the vessel in which it is enclosed, and leaves nothing but azotic gas. This fact was first observed by Scheele, and induced him to use sulphuret of potash for an *eudiometer*, or instrument to measure the quantity of oxygen contained in any given portion of atmospheric air.

If sulphuret of potash be allowed to remain moist, and in contact with the atmosphere, it is gradually converted into sulphat of potash by the sulphur combining with oxygen, and forming sulphuric acid. At the same time the sulphuret emits a fetid smell, which is known to be the odour of sulphurated hydrogen gas. The sulphuret then decomposes the water with which it is mixed. Very little sulphurated hydrogen gas, however, is emitted, except an acid (the sulphuric, for instance) be poured upon the mixture, and then it is given out very copiously. The reason of this is, that there is an affinity between the potash and this gas. Accordingly it is retained by the potash after it is formed. But as the acids have a much stronger affinity for potash, as soon as any of them is poured in the gas is obliged to separate †.

† *Ibid.* If liquid sulphuret of potash be kept in close vessels, it is not decomposed except in part; because as soon as the alkali is saturated with the sulphurated hydrogen gas, the action of the sulphur on the water is at an end. † *Ibid.*

The explanation of the action of this sulphuret on the atmosphere, which the Dutch chemists above-mentioned give from these data, is as follows:

Sulphuret of potash decomposes water; sulphurated hydrogen gas is formed, and absorbed by the alkali. This gas has a strong affinity for oxygen, which it absorbs from the atmosphere: the hydrogen combines with this oxygen, and forms water; and the sulphur is again precipitated, or rather left combined with the potash. Water is again decomposed by the attraction of the sulphur for oxygen; new sulphurated hydrogen gas is again formed; again absorbed; again attracts oxygen gas; and is again decomposed. And this process goes on till the whole of the sulphur has combined with oxygen, and consequently till the sulphuret is converted into a sulphat ‡.—The only part of this theory which requires confirmation, is the action of sulphurated hydrogen gas on oxygen gas, and the consequent formation of water. And this they have rendered not improbable, by shewing that sulphurated hydrogen gas combined with alkali has the property of absorbing oxygen gas from the atmosphere ||.

|| *Ibid.* p. 305. Potash unites with phosphorus by fusion, and forms a phosphuret of potash. Little is known concerning its properties, except that it produces phosphurated hydrogen gas.

† *Ibid.* p. 376. Potash seems also capable of combining with carbon.

Potash does not combine with the metals; but it unites with many of their oxides.

When

Alkalies. When a solution of potash is boiled upon silica recently procured, it dissolves part of it. As the solution cools, it assumes the appearance of a jelly, even though previously diluted with 17 times its own weight of water*.

* Bergman, ii. 37. When equal parts of silica and potash are melted together, they combine and form *glafs*. A substance which, whether we consider its hardness, beauty, and transparency, its amazing ductility, while hot, or the difficulty of decomposing it, must be allowed to be one of the most useful compounds ever invented by man.

When the quantity of potash is double or triple that of the silica, the glass is soluble in water, and forms what is called *liquor silicum*.

Potash seems also capable of combining in the same manner with barytes, lime, magnesia, and alumina; but these combinations have never been examined with attention. Lime, however, is often added to the materials for making glass, and is supposed to increase its hardness and solidity.

The metallic oxides have the property of rendering glass more fusible, and of communicating various colours to it; they accordingly very often make a part of its composition. The colours communicated by these oxides will appear from the following Table:

Metallic Oxides.	Colour communicated to Glass.
Oxide of gold and tin,	- Purple.
Silver, - - -	Yellow or golden.
Iron, - - -	Pale green.
Lead, - - -	Colourless.
Zinc, - - -	White.
Antimony, -	Green (N).
Arsenic, - - -	White.
Cobalt, - - -	Blue.
Nickel, - - -	Blue (O).
Manganese, -	Red.
Tungsten, - -	Colourless.
Molybdenum, -	Colourless.
Uranium, - - -	Grey (opaque).
Titanium, - - -	White (opaque).
Tellurium, - -	White.
Chromium, - -	Green.

378 Scop. Potash combines readily with fixed oils, and forms the compound known by the name of *soap*.

379 Potash, whether a compound. Potash has never yet been decomposed. Several chemists, indeed, have conjectured, that it was a compound of lime and azot; and some persons have even endeavoured to prove this by experiment; but none of their proofs are at all satisfactory. We ought, therefore, in strict propriety, to have assigned it a place in the first part of this article: but this would have separated the alkalies from each other, and would have introduced a confusion into the article, which would have more than counterbalanced the logical exactness of the arrangement. Besides, we are certain, from a variety of facts, that all the alkalies are compounds: One of them has actually been decomposed; and the other two have been detected in the act of formation, though the ingredients which compose them have not hitherto been discovered.

Alkalies. Whether potash contains lime is a different question. Were we to judge from analogy, we should suppose, that the four alkaline earths, and the three alkalies, possess one common principle. They have a great number of common properties, and perhaps ought to be classed altogether under the name of *alkalies*.

That azot enters into the composition of all these bodies, as Fourcroy has conjectured, is far from probable. One alkali, as we shall soon see, actually contains azot. But no conclusion can be drawn till future discoveries have lifted off the veil which at present obstructs our view.

The affinities of potash are as follows:

Sulphuric acid,
Nitric,
Muriatic,
Sebacic,
Fluoric,
Phosphoric,
Oxalic,
Tartarous,
Arsenic,
Succinic,
Citric,
Formic,
Lactic,
Benzoic,
Sulphurous,
Acetous,
Saccholarctic,
Boracic,
Nitrous,
Carbonic,
Prussic,
Oil,
Sulphur,
Phosphorus,
Water.

The place of the metallic oxides has not yet been ascertained.

SECT. II. Of Soda.

SODA, called *mineral alkali*, because it is found in the earth, was known to the ancients under the names of *νιτρον* and *nitrum* (P). It was long confounded with potash; and perhaps was never properly distinguished from it till Du Hamel published a paper on the subject in 1736.

Its properties, while pure, are precisely the same with those of potash, excepting only that its affinity for other bodies is not so strong; it does not, therefore, require any particular description. We ought to mention, however, that it differs from potash in one particular; potash attracts moisture in the air, but soda parts with it, and when exposed to the atmosphere, soon crumbles down into a dry powder.

It is capable of combining with all the substances with which potash unites; but it forms compounds possessed, in general, of very different properties from those of the compounds into which potash enters.

It

(N) If the glass be made with soda.

(O) But reddish if the glass be formed of soda. *Klaproth*.

(P) The *νιτρον* of the Athenians was evidently the same substance; and so was the *נתר* of the Hebrews.

Alkalies.

It is reckoned more proper than potafs for forming glafs and foap.

Some chemifts have fuppofed that it is compofed of magnesia and azot; but their proofs are infufficient.

The order of its affinities is the fame with that of potafs.

SECT. III. *Of Ammonia.*382
Discovery
of ammo-
nia.

AMMONIA (Q), volatile alkali, or *hartfborn*, as it is called in commerce, is mentioned as early as the 15th century. Both Bafil Valentine and Raymond Lully described the methods of procuring it. Dr Black was the first who diftinguifhed pure ammonia from the carbonat of ammonia, or ammonia combined with carbonic acid; and Dr Priefley first difcovered the method of obtaining it in a ftate of complete purity.

To obtain pure ammonia, mix common fal ammoniac with three parts of flacked lime; apply heat; and receive the product in a vefel filled with mercury ftanding in a bafon of mercury. A gas comes over, which

* Priefley on Air, iii. 371. is pure ammonia*. This gas is transparent like common air, and is not condensed by cold.

383
Its properties. Its fpecific gravity is 0,000732. It is to common air as 600 to 1000 †.

† Kirwan on Phlog. p. 28. It has a very ftrong, but not unpleafant fmell. Animals cannot breathe it without death. When a lighted candle is let down into this gas, it goes out three or four times fucceffively; but at each time the flame is confiderably enlarged by the addition of another flame of a pale yellow colour, and at laft this flame defcends from the top of the vefel to the bottom ‡.

‡ Priefley, ii. 381. Water abforbs this gas with avidity. It difappears almost infantly on the introduction of a little water. From an experiment of Dr Priefley, it appears that water faturated with this gas is of the fpecific gravity

§ Ibid. p. 372. 1,435 §. This water acquires the fmell of ammonia. It has a very ftrong difagreeable tafte, and converts vegetable colours to a green.

Ammonia in the ftate of gas has no effect upon fulphur or phofphorus. Carbon abforbs it; probably becaufe it contains water. Neither hydrogen nor azot produce any alteration on it ||.

|| Ibid. p. 377. Alcohol and ether abforb it in confiderable quantity ¶.

¶ Ibid. 384. Dr Priefley difcovered, that when electric explofions were made to pafs through this gas, its bulk was gradually augmented to thrice the fpace which it formerly occupied. It was then moftly converted into hydrogen gas. He difcovered, too, that heat produced the very fame effect*. Thefe experiments prove that hydrogen

* Ibid. 389. enters as an ingredient into the compofition of ammonia.

Mr Scheele obferved, that when ammonia was treated with the oxides of manganese, gold, or mercury, the oxides were reduced; the ammonia difappeared; and nothing remained but a quantity of azotic gas. Thefe facts induced Bergman to conjecture, that ammonia was compofed of hydrogen and azot: a conjecture which has been fully confirmed by the experiments of Berthollet.

This ingenious chemift obferved, that if oxy-muriatic acid and ammonia be mixed, an efferefcence takes place; azot is difengaged, a quantity of water formed,

and the oxy-muriatic acid is converted into common muriatic acid. Now the fubftances mixed were ammonia and oxy-muriatic acid, which is compofed of oxygen and muriatic acid; the products were, muriatic acid, azot, and water, which is compofed of oxygen and hydrogen.

The oxygen of the water was furnifhed by the acid; the other products muft have been furnifhed by the ammonia, which has difappeared. Ammonia, therefore, muft be compofed of azot and hydrogen. Mr Berthollet proved, that ammonia was compofed of thefe ingredients by a number of other experiments. For inftance, if the oxide of copper be heated in contact with ammoniacal gas, it is reftored to the metallic ftate; the ammonia difappears, a quantity of water is formed, and azotic gas is difengaged. It follows from Mr Berthollet's experiments, that ammonia is compofed of 121 parts of azot and 29 of hydrogen*. According to Dr Aftin, it is

compofed of 121 parts of azot, and 32 of hydrogen †.

After the compofition of ammonia had been thus afcertaind, it became a queftion of fome confequence, Whether it could be formed artificially? Dr Aftin accordingly mixed hydrogen and azotic gas together in the proper proportions, and endeavoured to make them combine by the application of heat, by electricity, and by cold; but he found, that while thefe two fubftances were in a gafeous ftate, they could not be combined by any method which he could devife. It could not be doubted, however, that the combination often takes place when thefe bodies are prefented to each other in a different form. Dr Priefley ‡ and Mr Kirwan || had actually produced it, even before its compofition was known.

Accordingly he found, that when tin is moiftened with nitric acid, and after being allowed to digeft for a minute or two, a little potafs or lime is added, ammonia is immediately exhald §. In that cafe, the nitric acid and

the water which it contains are decomposed; the oxygen of each unites with the tin, and reduces it to the ftate of an oxide; and at the fame time the hydrogen of the water combines with the azot of the acid, and forms ammonia, which is driven off by the ftronger affinity of the potafs or lime. Dr Aftin fucceeded alfo in forming ammonia by feveral other methods. He introduced into a glafs tube filled with mercury a little azotic gas, and then put into the gas fome iron filings moiftened with water. The iron decomposes the water and combines with its oxygen; and the hydrogen meeting with azot at the moment of its admiffion, combines with it, and forms ammonia. This experiment fhews, that the gafeous ftate of the azot does not prevent its combination with hydrogen.

Ammonia may be combined with fulphur by mixing together two parts of muriat of ammonia (ammonia combined with muriatic acid), two parts of lime, and one part of fulphur, and diftilling; a yellow liquor is obtained, which contains fulphuret of ammonia. It is capable of cryftallizing.

The phofphuret of ammonia is unknown.

Ammonia is capable of combining with feveral of the metallic oxides, particularly copper.

It combines with fixed oils, and forms foap.

The order of its affinities is precifely the fame with that of the fixed alkalies.

Alkalies.

* Mem. Par. 1785.

† Phil. Transf. 1788.

385

Formation of ammonia.

‡ On Air, ii.

41.

§ On Hepatic Air, § iii.

¶ Dr Auf-

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Sulphuret of ammonia.

nia.

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(Q) We have adopted this word, which is Dr Black's, becaufe we think it preferable to *ammoniac* or *ammoniacia*, the words propofed and ufed by the French chemifts.

Acids.

CHAP. V. Of ACIDS.

Acids.

387 Properties of acids.

SUBSTANCES possessed of the following properties are denominated acids.

1. When applied to the tongue they excite that sensation which is called *sour* or *acid*.
2. They change the blue colours of vegetables to a red. The vegetable blues employed for this purpose are generally tincture of litmus and syrup of violets or of radishes, which have obtained the name of *reagents* or *tests*. If these colours have been previously converted to a *green* by alkalis, the acids restore them again.
3. They unite with water in almost any proportion.
4. They combine with all the alkalis, and most of the metallic oxides and earths, and form with them those compounds which are called *neutral salts*.

It must be remarked, however, that every acid does not possess all these properties; but all of them possess a sufficient number of them to distinguish them from other substances. And this is the only purpose which artificial definition is meant to answer.

388 Theories about the acid principle.

Paracelsus believed that there was only one acid principle in nature, which communicated taste and solubility to the bodies in which it was combined. Becher embraced the same opinion; and added to it, that this acid principle was a compound of earth and water, which he considered as two elements. Stahl adopted the theory of Becher, and endeavoured to prove, that his acid principle was sulphuric acid; of which, according to him, all the other acids were mere compounds. But his proofs were only conjectures or vague experiments, from which nothing could be deduced. Nevertheless, his opinion, like every other which he advanced in chemistry, continued to have supporters for a long time, and was even countenanced by Macquer. At last its defects began to be perceived; Bergman and Scheele declared openly against it; and their discoveries, together with those of the French chemists, notwithstanding the ill-natured attempts of Monnet to support it, demonstrated the falsehood of both parts of the theory, by shewing that sulphuric acid did not exist in the other acids, and that it was not composed of water and earth, but of sulphur and oxygen.

The opinion, however, that acidity is owing to some principle common to all the salts, was not abandoned. Wallerius, Meyer, and Sage, had advanced different theories in succession about the nature of this principle; but as they were founded rather on conjecture and analogy than direct proof, they obtained but few advocates. At last Mr Lavoisier, by a number of ingenious and accurate experiments, proved, that several combustible substances when united with oxygen form acids; that a great number of acids contain oxygen; and that when this principle is separated from them, they lose their acid properties. He concluded, therefore, that the acidifying principle is oxygen, and that acids are nothing else but combustible substances combined with oxygen, and differing from one another according to the nature of the combustible base. This conclusion has been con-

389 Lavoisier's theory.

firmed by every subsequent observation. All the acids hitherto analysed contain oxygen, one perhaps excepted, the Pruffic acid, which possesses properties so different from the rest, that it might, without great impropriety, be placed in a distinct class. It is probable, therefore, that those acids which it has not yet been possible to decompose consist of oxygen combined with a combustible base: but till this analysis has actually been accomplished, the theory of Mr Lavoisier cannot be considered as completely demonstrated (R).

The acids at present known amount to about 39, most of which have been examined within these 30 years. Their names are as follows:

390 List of the acids.

- | | |
|--------------------|--------------------|
| 1. Sulphuric acid, | 21. Benzoic, |
| 2. Sulphurous, | 22. Succinic, |
| 3. Nitric, | 23. Camphoric, |
| 4. Nitrous, | 24. Suberic, |
| 5. Muriatic, | 25. Laccic, |
| 6. Oxy muriatic, | 26. Pyromucous, |
| 7. Phosphoric, | 27. Pyrolignous, |
| 8. Phosphorous, | 28. Pyrotartarous, |
| 9. Boracic, | 29. Pruffic, |
| 10. Fluoric, | 30. Formic, |
| 11. Carbonic, | 31. Sebacic, |
| 12. Acetic, | 32. Bombic, |
| 13. Acetous, | 33. Zoonic, |
| 14. Oxalic, | 34. Arfenic, |
| 15. Tartarous, | 35. Tungstic, |
| 16. Citric, | 36. Molybdic, |
| 17. Malic, | 37. Chromic, |
| 18. Lactic, | 38. Platinic, |
| 19. Saccholaric, | 39. Stannic, |
| 20. Gallic, | |

These acids shall form the subject of the following sections.

SECT. I. Of Sulphuric Acid.

SULPHUR combines with two different quantities of oxygen: with the smaller quantity it forms *sulphurous acid*; with the larger *sulphuric acid*. The last of these is the subject of the present section.

391 Discovery of sulphuric acid.

The ancients were acquainted with some of the compounds into which sulphuric acid enters; *alum*, for instance, and *green vitriol*: but they appear to have been ignorant of the acid itself. It is first mentioned in the works of Basil Valentine, which were published about the end of the 15th century.

It was for a long time obtained by distilling *green vitriol*, a salt composed of sulphuric acid and green oxide of iron; hence it was called *oil of vitriol*, and afterwards *vitriolic acid*. Another method of obtaining it was by burning sulphur under a glass bell; hence it was called also *oleum sulphuris per campanam*. The French chemists in 1787, when they formed a new chemical nomenclature, gave it the name of *sulphuric acid*.

392 Method of procuring it.

At present it is generally procured by burning a mixture of sulphur and nitre in chambers lined with lead. The theory of this process requires no explanation. The nitre supplies a quantity of oxygen to the sulphur,

(R) This theory has been carried so far by some chemists, that they have considered it as a conclusive proof that oxygen did not enter into the composition of a body, if they could shew that the body was not an acid. Thus, according to them, *water* cannot contain oxygen, because water is not an *acid*.—But surely no theory, however ingenious and satisfactory, can for a moment be put in competition with experiment. The ways of Nature are not as our ways, nor her thoughts as our thoughts.

Sulphuric Acid.

Sulphuric Acid.

393 Its component parts.

* Mem. Par. 1781, 232.

† Mem. Par. 1782, 603.

394 Its properties.

395 Its crystallals.

† Encyc. Method. Chim. i. 376.

§ Journ. de Phys. xxxi. 473.

fulphur, and the air of the atmosphere furnishes the rest. The acid thus obtained is not quite pure, containing a little potash, some lead, and perhaps also nitric and sulphurous acids. These acids may be driven off by applying for some time a gentle heat, and afterwards the fulphuric acid itself may be distilled over pure.

It appears from an experiment of Mr Berthollet, that sulphuric acid contains 63,2 parts of sulphur, and 36,8 of oxygen. He ascertained, in the first place *, that nitre is totally decomposed by being heated with $\frac{1}{4}$ th of sulphur. He then mixed together 288 grains of nitre and 72 of sulphur; and after exposing them to a sufficient heat, he found 12 grains of sulphur sublimed, and 228 grains of sulphat of potash †. But the sum of the ingredients was 360 grains; consequently 120 grains have been dissipated. All this loss must have been suffered by the acid of the nitre, for the heat was too small to separate any of the alkali. According to Mr Kirwan, 288 grains of nitre contain 132,96 of alkali, and 155,04 of acid. $155,04 - 120 = 35,04 =$ quantity of oxygen furnished by the nitre to convert 60 grains of sulphur into acid.

Sulphuric acid is a liquid, somewhat of an oily consistence, transparent and colourless as water, without any smell, and of a very strong acid taste. When applied to animal or vegetable substances, it very soon destroys their texture.

It always contains a quantity of water; part of which, however, may be driven off by the application of a moderate heat. This is called *concentrating the acid*. When as much concentrated as possible, its specific gravity is 2,000.

It changes all vegetable blues to a red, except indigo. According to Erxleben, it boils at 546°; according to Bergman, at 572°.

When exposed to a sufficient degree of cold, it crystallizes or freezes; and after this has once taken place, it freezes again by the application of a much inferior cold. Moreveau froze it at -4°; it assumed the appearance of frozen snow. After the process began it went on in a cold not nearly so intense. The acid melted slowly at 27,5°; but it froze again at the same temperature, and took five days to melt in the temperature of 43° †. Chaptal, who manufactured this acid, once observed a large glass vessel full of it crystallized at the temperature of 48°. These crystals were in groups, and consisted of flat hexahedral prisms, terminated by a six sided pyramid. They felt hotter than the surrounding bodies, and melted on being handled §. Chaptal has observed, that sulphuric acid, in order to crystallize, must not be too concentrated. This observation has been extended a good deal further by Mr Keir. He found, that sulphuric acid, of the specific gravity of 1,780, froze at 45°; but if it was either much more

or much less concentrated, it required a much greater cold for congelation *.

Sulphuric acid has a very strong attraction for water. Neumann found, that when exposed to the atmosphere it attracted 6,25 times its own weight. Mr Gould found, that 180 grains of acid, when exposed to the atmosphere, attracted 68 grains of water the first day, 58 the second, 39 the third, 23 the fourth, 18 the fifth, and at last only 5, 4, 3, 4, 3, &c. The 28th day, the augmentation was only half a grain †. The affinity therefore between sulphuric acid and water, as is the case in general with other substances, becomes weaker the nearer they approach to saturation. He does not specify the specific gravity of his acid; but as it only attracted 3,166 times its own weight, it could not have been very concentrated.

When sulphuric acid is mixed with water, a great quantity of caloric is evolved. A mixture of equal parts of these liquids causes a heat almost equal to that of boiling water. Lavoisier and De la Place found, that when 2,625 lbs. troy of sulphuric acid, of the specific gravity 1,87058, was mixed with 1,969 lbs. troy of water, as much caloric was evolved as melted 4,1226 pounds troy of ice, or as much caloric as the acid and water would have given out had they been heated without mixture to 155,9° †. This caloric is owing chiefly, if not solely, to the increase of density in the water; for when equal quantities of sulphuric acid and water are mixed together, the specific gravity is much greater than the mean; and it has been formerly shewn, that whenever bodies become denser they give out caloric.

Since there is such a strong affinity between sulphuric acid and water, and since the density of the mixture is different from the mean density of the ingredients, it becomes a problem of the greatest importance to determine how much of the strongest sulphuric acid that can be prepared exists in any given quantity of sulphuric acid of inferior specific gravity, and which consequently consists of a determined quantity of this strong acid diluted with water.

This problem has been solved by Mr Kirwan §. He took sulphuric acid of the specific gravity 2,000, which is the strongest that can be procured, for his standard, and the point was to determine how much of this standard acid existed in a given quantity of acid of inferior density.

He concluded, from a number of experiments with sulphuric acid, of the specific gravities 1,8846, 1,8689, 1,8042, 1,7500 (for he could not procure an acid of the specific gravity 2,000 at the temperature of 60°, in which his experiments were performed), that when equal parts of standard acid and water are mixed, the density is increased by $\frac{1}{7}$ th part of the whole mixture. Then, by applying a formula given by Mr Poujet (s), he calculated, that the increase of density, on mixing

Q q different

(s) Mr Poujet undertook the examination of the specific gravity of alcohol mixed with different quantities of water. He took for his standard alcohol whose specific gravity was 0,8199, at the temperature of 65,75°. He then formed ten mixtures; the first containing nine measures of alcohol and one of water, the second eight measures of alcohol and two of water, and so on, till the last contained only one measure of alcohol and nine of water. He took care that each of these measures should contain equal bulks, which he ascertained by weight, observing that a measure of water was to a measure of alcohol as 1 to 0,8199. Thus 10000 grains of water and 8199 of alcohol formed a mixture containing equal bulks of each. From the specific gravity of each of these mixtures he discovered how much they had diminished in bulk in consequence of mixture, by the following method.

Calling

* Phil. Trans. lxxvii. Part ii. Its affinity for water. † Phil. Trans. 1684.

† Mem. Par. 1780.

397 Strength of sulphuric acid of various densities.

§ Irish Trans. iv.

Sulphuric Acid. different quantities of standard acid and water, was as in the following table :

Number of part. of water.	Number of parts of standard acid.	Augmentation of density.
5	95	0,0252
10	90	0,0479
15	85	0,0679
20	80	0,0856
25	75	0,0699
30	70	0,1119
35	65	0,1213
40	60	0,1279
45	55	0,1319
50	50	0,1333

The first 50 numbers of the following table were formed by adding these augmentations to the specific gravity of the above mixture found by calculation, and taking the arithmetical mean for the intermediate quantities. The remaining numbers were formed from actual observation. He found by the first part of the table, that 100 parts of acid, of the specific gravity 1,8472, contained 88,5 parts standard, consequently

400 grains of this acid contain 354 grains standard. He took six portions of this acid, each containing 400 grains, and added to them as much water as made them contain respectively 48, 46, 44, 42, 40, 38 grains standard. The quantity of water to be added in order to produce this effect, he found by the following method. Suppose x = the quantity of water to be added to 400 parts of acid, that the mixture may contain 48 per cent. of standard acid. Then $400 + x : 354 :: 100 : 48$, and consequently $x = 337,5$. After finding the specific gravity of these, the half of each was taken out, and as much water added; and thus the specific gravities, corresponding to 24, 23, 22, 21, 20, 19, were found. Then six more portions, of 400 grains each, were taken, of the specific gravity 1,8393, and the proper quantity of water added to make them contain 36, 34, 32, 30, 28, 26 per cent. of standard. Their specific gravities were found, the half of them taken out, and as much water added; and thus the specific gravity of 18, 17, 16, 15, 14, and 13 found. Care was taken, after every addition of water, to allow the ingredient sufficient time to unite.

The last 11 numbers were only found by analogy; observing the series of decrement of the four last numbers before them.

TABLE

Calling A the real specific gravity of any of the mixtures; B its specific gravity found by calculation, supposing no diminution of bulk; n the number of measures composing the whole mass; $n - x$ the number to which it is reduced in consequence of mutual penetration—it is evident, since the increase of density does not diminish

the weight of the whole mass, that $nB = n - x \times A$. Therefore $x = \frac{A - B}{A} \times n$, or (making $n = 1$) = $\frac{A - B}{A}$. $\frac{A - B}{A}$ is therefore the diminution of volume produced by the mixture.

The following table contains the result of Mr Poujet's experiments, calculated according to that formula; the whole volume or n being = 1.

Measures of		Diminution of the whole volume = 1 by experiment.	By calculation.
Water.	Alcohol.		
1	9	0,0109	0,0103
2	8	0,0187	0,0184
3	7	0,0242	0,0242
4	6	0,0268	0,0276
5	5	0,0288	
6	4	0,0266	0,0276
7	3	0,0207	0,0242
8	2	0,0123	0,0184
9	1	0,0044	0,0103

It is evident, from this table, that the diminution of the bulk of the mixture follows a regular progression. It is greatest when the measures of water and alcohol are equal, and diminishes as it approaches both ends of the series. Mr Poujet accounts for this by conceiving the alcohol to be dissolved in the water, which retains a part of it in its pores, or absorbs it. The quantity absorbed ought to be in the ratio of that of the solvent and of the body dissolved, and each measure of water will retain a quantity of alcohol proportional to the number of measures of alcohol in the mixture. Thus in a mixture formed of nine measures of alcohol and one of water, the water will contain a quantity of alcohol = 9; in one of eight measures of alcohol and two of water, the water will contain a quantity of alcohol = 8. Therefore the diminution of bulk in each mixture is in a ratio compounded of the measures of alcohol and water which form it; in the above table, as 1×9 , 2×8 , 3×7 , 4×6 , &c. And in general, taking the diminution of bulk when the measures of both liquids are equal for a constant quantity, and calling it ϵ , calling the number of measures n , the number of measures of alcohol x , the increase of density

TABLE of the Quantity of Standard Sulphuric Acid, Specific Gravity 2,000 in Sulphuric Acid of inferior Density, Temperature 60°.

100 parts, at the specific gravity	Contain of stand-ard acid	100 parts, at the spe-cific gra-vity	Contain of stan-dard acid	100 parts, at the spe-cific gra-vity	Contain of stan-dard acid
2,000	100	1,6217	67	1,2847	34
1,9859	99	1,6122	66	1,2757	33
1,9719	98	1,6027	65	1,2668	32
1,9579	97	1,5932	64	1,2589	31
1,9439	96	1,5840	63	1,2510	30
1,9299	95	1,5748	62	1,2415	29
1,9168	94	1,5656	61	1,2320	28
1,9041	93	1,5564	60	1,2210	27
1,8914	92	1,5473	59	1,2101	26
1,8787	91	1,5385	58	1,2009	25
1,8660	90	1,5292	57	1,1918	24
1,8542	89	1,5202	56	1,1836	23
1,8424	88	1,5112	55	1,1746	22
1,8306	87	1,5022	54	1,1678	21
1,8188	86	1,4933	53	1,1614	20
1,8070	85	1,4844	52	1,1531	19
1,7959	84	1,4755	51	1,1398	18
1,7849	83	1,4666	50	1,1309	17
1,7738	82	1,4427	49	1,1208	16
1,7629	81	1,4189	48	1,1129	15
1,7519	80	1,4099	47	1,1011	14
1,7416	79	1,4010	46	1,0955	13
1,7312	78	1,3875	45	1,0896	12
1,7208	77	1,3741	44	1,0833	11
1,7104	76	1,3663	43	1,0780	10
1,7000	75	1,3586	42	1,0725	9
1,6899	74	1,3473	41	1,0666	8
1,6800	73	1,3360	40	1,0610	7
1,6701	72	1,3254	39	1,0555	6
1,6602	71	1,3149	38	1,0492	5
1,6503	70	1,3102	37	1,0450	4
1,6407	69	1,3056	36	1,0396	3
1,6312	68	1,2951	35	1,0343	2

Sulphuric Acid. 398 Quantity of real acid in strong sulphuric acid.

But we have no reason to suppose that sulphuric acid, at the density 2,000, is free from all mixture of water; so far from that, we know for certain that it contains a considerable proportion; for when it is combined with other bodies, barytes, for instance, or potash, there is a considerable quantity of water which remains behind, and does not enter into the combination. Now, is it possible to determine what would be the density of sulphuric acid, supposing it to be deprived of all water, or at least of all water except what is necessary for its existence as an acid? or to determine, how much real acid exists in a given quantity of standard acid?

Homberg first attempted to answer this question. It was afterwards undertaken by Bergman, and Wenzel, and Wiegleb. They do not inform us of the quantity of water contained in a given weight of acid, but they put it in our power to find it, by informing us how much real acid is necessary to saturate a given quantity of potash. Their respective experiments give the following numbers:

	Homb.	Berg.	Wenzel.	Wiegleb.
100 parts of pot-ash require	38,3	78,5	82,63	101,92.

Homberg used carbonat of potash, and did not take into consideration the carbonic acid driven off by the sulphuric. When this is taken in, his number should be 54 instead of 38,3.

Now to discover the quantity of real acid in any sulphuric acid mixture, we have only to find out how much potash it would require for saturation. The differences between the above results are so great, that there was reason to suspect their accuracy. Mr Kirwan therefore attempted to ascertain the density of pure sulphuric acid by another method, and he rated it at 4,226. As this method has been already described in the article CHEMISTRY, *Encycl.* we cannot enter upon it here. At any rate, it would be unnecessary, as many of the principles upon which Mr Kirwan went were erroneous, as Mr Morveau* and Mr Keir † have sufficiently shewn; * *Encyc. Method. art.* and Mr Kirwan, with his usual candour, has accordingly abandoned it, and adopted another method which † *Keir's Dictionary, Art.* is not liable to the same exceptions. He dissolved 1523,5 grains art. Acid.

Q q 2

density or diminution of bulk z ; we shall have $c : z :: \frac{n}{2} \times \frac{n}{2} : n - x, \times x$ and $z = \frac{4c}{n^2} \times nx - x^2$, or (making $n = 1$) $= 4cx^2$.

The diminution of bulk, calculated according to this formula, make the last column of the above table. They correspond very well with experiment, while the measures of alcohol are more than those of water, but not when the reverse is the case. This Mr Poujet thinks is owing to the attraction which exists between the particles of water, and which, when the water is considerable compared with the alcohol, resists the union of the water with the alcohol.

By the formula $z = \frac{4cnx - 4cx^2}{n^2}$, the quantity of alcohol of the standard may be determined in any mixture where the alcohol exceeds the water.

Let the number of measures, or the whole mass	-	-	-	-	= 1
The measures of alcohol	-	-	-	-	= x
The diminution of bulk at equal measures	-	-	-	-	= c
The diminution of bulk of a mixture containing x measures of alcohol	-	-	-	-	= $4cx - 4cx^2$
The specific gravity of water	-	-	-	-	= a
The specific gravity of the alcohol	-	-	-	-	= b
The specific gravity of the unknown mixture	-	-	-	-	= y

Sulphuric Acid.

Sulphuric Acid.

grains of pure carbonat of potafs, dried in a red heat, in distilled water. The whole weighed 4570 grains. He took 360 grains of this mixture, which contained 120 grains of carbonat of potafs, and saturated it with pure sulphuric acid of the specific gravity 1,565, which, according to the above table, contained 61 per cent. of standard acid. The acid required for saturating the solution of potafs amounted to 130 grains, and contained therefore 79 of standard. The carbonic acid disengaged was 34 grains, and consequently the quantity of alkali was 120 - 34 = 86 grains. The solution being turbid, was diluted with 3238 grains of water. Its specific gravity was then 1,013 at the temperature of 60°. The weight of the whole was 3694 grains. Forty-five grains of sulphat of potafs (potafs combined with sulphuric acid), dissolved in 1017 grains of distilled water, have the same specific gravity at the same temperature; from whence it follows, that the proportion of salt in each was equal. But in the last solution the quantity of salt was $\frac{1}{23,6}$ of the whole; therefore the quantity of salt in the first was $\frac{3694}{23,6} = 159,52$ grs. Now

of this weight 86 grains were alkali; the remainder, therefore, which amounts to 70,52 grains, must be acid. But the quantity of standard acid employed was 79 grains; of this there were 8½ grains which did not enter into the combination, and which must have been pure water: 79 parts of standard acid, therefore, contain at least 8,5 parts of water, and consequently 100 parts of standard acid contain 10,75 parts of water. It only remains now to consider how much water sulphat of potafs contains. Mr Kirwan thinks it contains none, because it loses no weight in any degree of heat below ignition, and even when exposed to a red heat for half an hour it hardly loses a grain. This is certainly sufficient to prove, at least, that it contains very little water; and consequently we may conclude, with Mr Kirwan, that 100 parts of sulphuric acid, of the specific gravity 2,000, are composed pretty nearly of 89,25 of pure acid and 10,75 of water. This method used by Mr Kirwan is nearly the same with that proposed by Mr Keir*.

It seems even possible to obtain sulphuric acid free from all the water that may not be necessary to its acid state. When it is procured by distillation from green vitriol, if the receiver be changed after the process has gone on for some time, a quantity of acid is obtained in

a solid form, or crystallized. This, as Morveau has shewn, is sulphuric acid deprived of the water with which it is usually combined. When this *glacial acid*, as it has been called, is exposed to the air, it rises in white fumes, and is soon dissipated. This singular effect is produced by its violent attraction for the water which exists in atmospheric air. When thrown into water, it seizes it with violence; a great deal of caloric is evolved, sufficient, if the quantity of water be not too great, to elevate the whole in vapours*.

Sulphuric acid is capable of decomposing alcohol and oils; and when assisted by heat, it decomposes also some of the metallic oxides which contain the greatest quantity of oxygen; as red oxide of lead, black oxide of manganese. It decomposes likewise all the sulphurets and phosphurets which have an alkaline or earthy basis.

It oxidates iron, zinc, and manganese, in the cold. By the assistance of heat it oxidates silver, mercury, copper, antimony, bismuth, arsenic, tin, and tellurium. At a boiling heat it oxidates lead, cobalt, nickel, molybdenum. It does not act upon gold, platinum, tungsten, nor titanium.

It unites readily with all the alkalies, the alkaline earths, alumina, and jargonina, and with most of the metallic oxides, and forms salts denominated *sulphats*. Thus the combination of sulphuric acid and soda is called *sulphat of soda*; the compound of sulphuric acid and lime, *sulphat of lime*, and so on. It does not act upon silica nor adamanta.

The affinities of sulphuric acid are as follows †:

- Barytes,
- Strontites †,
- Potafs,
- Soda,
- Lime,
- Magnesia,
- Ammonia,
- Alumina,
- Jargonina §?
- Oxide of zinc,
- iron,
- manganese,
- cobalt,
- nickel,
- lead,
- tin,
- copper,
- bismuth,

* Encyc. Method. Chim. i. 590.
399
Action of this acid on other bodies.

400
Its affinities.
† See Bergman and Lavoisier.
‡ Dr Hope, Transf. Edin. iv.

§ Vauquelin, Ann. de Chim. xxii. 208.

Oxide

Then since the increase of density does not change the weight of the whole, $1 - x \times a + b x =$

$$1 - 4cx + 4cx^2 \times y.$$

$$\text{Hence } x = 0,5 - \frac{a-b}{8cy} + \sqrt{\frac{a-y}{4cy} + \left(\frac{a-b}{8cy} - 0,5\right)}$$

$$y = \frac{a - ax + bx}{1 - 4cx + 4cx^2}$$

And making $a = 1, b = 0,8199, c = 0,0288$

$$x = 0,5 - \frac{0,1801}{0,2304y} + \sqrt{\frac{1-y}{0,1152y} + \left(\frac{0,1801}{0,2304y} - 0,5\right)}$$

$$y = \frac{1 - 0,1801x}{1 - 0,1152x + 0,1152x^2} \quad \text{See Irish Transf. III.}$$

* Keir's Dictionary, art. Acid.

Part II.

Sulphurous Acid.

- Oxide of antimony,
- arfenic,
- mercury,
- silver,
- gold,
- platinum,
- Oil,
- Water.

SECT. II. Of Sulphurous Acid.

⁴⁰¹ Component parts of sulphurous acid. SULPHUROUS acid is composed of sulphur and oxygen combined: the proportions have not been ascertained; but the fact itself, and that the quantity of oxygen is less than what enters into sulphuric acid, has been proved beyond the possibility of doubt. Neither can it be doubted, though the fact has not been attended to, that in this acid the sulphur and oxygen mutually saturate each other; and that sulphuric acid is not composed of sulphur and oxygen, but of sulphurous acid and oxygen. Phosphorus is capable of decomposing sulphuric acid by the assistance of heat, of seizing a quantity of its oxygen, and converting it into sulphurous acid; but upon sulphurous acid it has no effect whatever*. The affinity of phosphorus therefore for oxygen is less than that of sulphur; yet it is capable of taking oxygen from sulphuric acid. Is it not evident from this, that sulphuric acid is composed of sulphurous acid and oxygen? and that sulphur has a stronger affinity for oxygen than sulphurous acid has? For if both the acids were composed directly of sulphur and oxygen, it would follow from experiment, that the affinity of phosphorus for oxygen was both stronger and weaker than that of sulphur; which would be absurd.

* Fourcroy and Vauquelin.

⁴⁰² Its discovery.

Sulphurous acid has been known since the time of Stahl. Scheele first discovered the method of obtaining it in quantities; and Dr Priestley first procured it in a state of purity; for Scheele's acid was dissolved in water.

⁴⁰³ Method of procuring it.

Stahl's method of procuring sulphurous acid was to burn sulphur at a low temperature, and expose to its flames cloth dipped in a solution of potash. By this method he obtained a combination of potash and sulphurous acid; for at a low temperature sulphur forms by combustion only sulphurous acid. On this salt Scheele poured a quantity of tartarous acid, and then applied a gentle heat. The sulphurous acid is in this manner displaced, because its affinity for potash is not so strong as that of tartarous acid; and it comes over into the receiver dissolved in water. It is now commonly procured by mixing with sulphuric acid oil, grease, metals, or any other substance that has a stronger affinity for oxygen than sulphurous acid, and applying a heat sufficient to distil over the sulphurous acid as it forms. Mr Berthollet has found, that sugar is the best substance to employ for this purpose.

Dr Priestley poured a little oil on sulphuric acid, applied heat, and received the product in a glass jar filled with mercury. It was sulphurous acid free from all superfluous water, and in a gaseous form.

⁴⁰⁴ Its properties.

In this state it is colourless and invisible like common air. It is incapable of maintaining combustion; nor can animals breathe it without death. It has a strong and suffocating odour. It is this odour which burning sulphur exhales. Its specific gravity, according to Berg-

man, is 0,00246* ; according to Lavoisier, 0,00251†. Sulphurous Clouet and Mongé found, that by the application of extreme cold it is converted into a liquid.

Dr Priestley discovered, that when a strong heat is applied to this acid in close vessels, a quantity of sulphur is precipitated, and the acid is converted into sulphuric‡. Berthollet obtained the same result: but Fourcroy and Vauquelin could not succeed§.

Water absorbs this acid with avidity. According to Dr Priestley, 1000 grains of water, at the temperature 54,5°, absorb 39,6 grains of this acid. The specific gravity of water saturated with sulphurous acid is 1,040||. Water in the state of ice absorbs it very rapidly, and is instantly melted. Water saturated with this acid can be frozen without parting with any of it. When water, which has been saturated with this acid at the freezing temperature, is exposed to the heat of 65,25°, it is filled with a vast number of bubbles, which continually increase and rise to the surface. These bubbles are a part of the acid separating from it. It freezes a few degrees below 32¶.

Sulphuric acid absorbs it at zero; but allows great part of it to escape at 32*.

It reddens tincture of turnsol; but destroys the colour of syrup of violets.

It is decomposed by hydrogen and carbon, and sulphurated hydrogen gas, when assisted by heat†.

Oxygen gas gradually converts it into sulphuric acid; but this change does not take place unless water be present.

It does not seem capable of oxidating any of the metals except iron, zinc, and manganese.

When in the state of gas it is absorbed by oils and ether.

When glass tubes, filled with sulphurous acid in the state of gas, are exposed to a strong heat, a quantity of sulphur precipitates, and the rest of the acid is converted into the sulphuric.

It combines with the alkalies, alkaline earths, and alumina, and many of the metallic oxides, and forms neutral salts, known by the name of *sulphites*.

Its affinities, as far as they have been investigated, are as follows ‡:

- Barytes,
- Lime,
- Potash,
- Soda,
- Magnesia, }
- Ammonia, }
- Alumina,
- Jargonia*?
- Metallic oxides,
- Water.

⁴⁰⁵ Its combinations.

⁴⁰⁶ And affinities.

* Vauquelin, Ann. de Chim. xxii. 208.

SECT. III. Of Nitric Acid.

THERE are three different substances composed of azot and oxygen, *nitric acid*, *nitrous acid*, and *nitrous gas*. The first contains most oxygen; the last contains least.

Nitric acid seems to have been first obtained in a separate state by Raymond Lully, who was born at Majorca in 1235. He procured it by distilling a mixture of nitre and clay. Basil Valentine, who lived in the 15th century, describes the process minutely, and calls the acid *water of nitre*. It was afterwards denominated

⁴⁰⁷ Discovery of nitric acid.

Nitric acid.
408
Method of procuring it.

ted *aqua fortis* and *spirit of nitre*. The name *nitric acid* was first given it in 1787 by the French chemists.

Nitric acid is generally obtained in large manufactories by distilling a mixture of nitre (τ) and clay; but the acid procured by this process is weak and impure. Chemists generally prepare it by distilling three parts of nitre and one of sulphuric acid in a glass retort. This method was first used by Glauber. When obtained in this manner it contains some nitrous acid, which may be expelled by the application of a very gentle heat*.

Nitric acid is one of the most important instruments of analysis which the chemist possesses; nor is it of inferior consequence when considered in a political or commercial view, as it forms one of the most essential ingredients of gunpowder. Its nature and composition accordingly have long occupied the attention of philosophers. We shall endeavour to trace the various steps by which its component parts were discovered.

As nitre is often produced upon the surface of the earth, and never except in places which have a communication with atmospheric air, it was natural to suppose that air, or some part of the air, entered into the composition of nitric acid. Mayow having observed, that nitre and atmospheric air were both possessed of the property of giving a red colour to the blood, and that air was deprived of this property by combustion and respiration - concluded, that nitre contained that part of the air which supported combustion, and was necessary for respiration.

Dr Hales, by applying heat to nitric acid, and what he called *Walton mineral*, obtained a quantity of air possessed of singular properties. When atmospheric air was let into the jar which contained it, a reddish turbid fume appeared, a quantity of air was absorbed, and the remainder became transparent again*. Dr Priestley discovered that this air could only be obtained from nitric (ν) acid; and therefore called it *nitrous air*. He found that when this gas was mixed with oxygen gas, nitrous acid was reproduced. Here, then, we find, that oxygen is a part of the nitric acid, and consequently that Mayow's affirmation is verified.

Dr Priestley, however, explained this fact in a different manner. According to him, nitrous gas is composed of nitrous acid and phlogiston. When oxygen is added, it separates this phlogiston, and the acid of course is precipitated. This hypothesis was adopted by Macquer and Fontana; and these three philosophers endeavoured to support it with their usual ingenuity. But there was one difficulty which they were unable to surmount. When the two gases are mixed in proper proportions, almost the whole assumes the form of nitric acid; and the small residuum ($\frac{1}{22}$ th part), in all probability, or rather certainly, depends on some accidental impurity in the oxygen gas. What then becomes of the oxygen and phlogiston? Dr Priestley supposed that they formed carbonic acid gas: but Mr Cavendish proved, that when proper precautions are taken, no such acid appears †.

* *Subtle.*

409
Discovery of its component parts.

* *Veget. Statics,* ii. 284.

† *Phil. Transf.* 1784.

Nitric Acid.

Dr Priestley had procured his nitrous gas by dissolving metals in nitric acid; during the solution of which a great deal of nitrous gas escapes. He supposed that nitrous gas contained phlogiston, because the metal was oxidated (and consequently, according to the then received theory, must have lost phlogiston) during its formation. Mr Lavoisier proved that this supposition was ill-founded by the following celebrated experiment*: * *Mem. Par.* 1776, p. 673.

To 945 grains of nitric acid (specific gravity 1,316) he added 1104 grains of mercury. During the solution 273,234 cubic inches of nitrous gas were produced. He then distilled the salt (oxide of mercury) which had been formed to dryness. As soon as it became red hot it emitted oxygen gas, and continued to do so till almost the whole of the mercury was revived: The quantity of oxygen emitted was 287,742 cubic inches. All that had happened, therefore, during the solution of the mercury, was the separation of the acid into two parts; nitrous gas, which flew off, and oxygen, which united with the metal (x).

Mr Lavoisier concluded, therefore, that the whole of the nitrous gas was derived from the nitric acid; that nitric acid is composed of oxygen and nitrous gas; and that the proportions are nearly 64 parts by weight of nitrous gas, and 36 of oxygen gas.

But there was one difficulty which Mr Lavoisier acknowledged he could not remove. The quantity of oxygen obtained by decomposing nitric acid was often much greater than what was necessary to saturate the nitrous gas. Mr De Morveau attempted to account for this; but without success†. Nitrous gas itself was evidently a compound; but the difficulty was to discover the ingredients. Mr Lavoisier concluded, from an experiment made by decomposing nitre by means of charcoal, that it contained azot: and several of Dr Priestley's experiments led to the same result. But what was the other ingredient?

Mr Cavendish had observed, while he was making experiments on the composition of water, that some nitric acid was formed during the combustion of oxygen and hydrogen gas, and that its quantity was increased by adding a little azot to the two gases before the explosion. Hence he concluded that the formation of the acid was owing to the accidental presence of azotic gas. To verify this conjecture, he passed an electrical shock through a quantity of common air enclosed in a glass tube: the air was diminished, and some nitric acid formed. He repeated the experiment, by mixing together oxygen and azotic gas; and found that when they bore a certain proportion to each other, they were totally convertible into nitric acid. In one experiment, the proportion of azot to oxygen (in bulk) was as 416 to 914; in another, as 1920 to 4860 ‡.

These experiments were immediately repeated by Messrs Van Marum and Van Troostwyk, and with nearly the same result. *Phil. Transf.* 1783.

The most convenient method of performing them is the following: Take a glass tube, the diameter of which

(τ) Nitre is composed of nitric acid and potash.

(ν) Or nitrous acid: for at the period of Dr Priestley's discovery (1772) they were not accurately distinguished.

(x) We have already mentioned, in a preceding note, that this experiment was first made by Mr Bayen. See Part I. chap. iii. of this Article.

CHEMISTRY.

Part II.

Nitric Acid.

which is about the sixth part of an inch, through the cork that shuts one end of which let a small metallic conductor pass with a ball at each end. Fill this tube with mercury, and plunge its open end into a basin of mercury: then put into it a mixture of 0,13 of azotic and 0,87 of oxygen gas, till it occupies three inches of the tube; and introduce a solution of potash till it fill half an inch more. Then, by means of the conductor, make electrical explosions (from a very powerful machine) to pass through the tube till the air is as much diminished as possible. Part of the potash will be found converted into nitre. Mr Cavendish actually saturated the potash with this acid. Mr Van Marum did not, though a good deal more gas had disappeared than in the experiments of Mr Cavendish. This difference evidently depends on the quantity of potash contained in a given weight of the solution. The solution which Mr Van Marum used was no doubt stronger than that which Mr Cavendish employed.

Dr Priestley had observed, several years before these experiments were made, that atmospheric air was diminished by the electric spark, and that during the diminution the infusion of turnsol became red; but he concluded merely that he had precipitated the acid of the air. Landriani, who thought, on the contrary, that carbonic acid gas was formed, enounced the alteration of lime-water by it as a proof of his opinion. It was to refute this notion that Mr Cavendish undertook his experiments. He has since that time repeated them with the same success*.

It cannot be doubted, then, that nitric acid is composed of azot and oxygen; for the objections of Dr Priestley have been considered while we were treating of water. Consequently nitrous gas must also be composed of the same ingredients. According to Lavoisier, nitric acid is composed of four parts, by weight, of oxygen and one part of azot.

Nitric acid is liquid, colourless, and transparent; but the affinity between its component parts is so weak, that the action of light is sufficient to drive off a part of its oxygen in the form of gas; and thus, by converting it partly into nitrous acid, to make it assume a yellow colour. Its taste is exceedingly acid and peculiar. It is very corrosive, and tinges the skin of a yellow colour, which does not disappear till the epidermis comes off.

It has a strong affinity for water, and has never yet been obtained except mixed with that liquid. When concentrated, it attracts moisture from the atmosphere, but not so powerfully as sulphuric acid. It also produces heat when mixed with water, owing evidently to the concentration of the water.

The specific gravity of the strongest nitric acid that can be procured is, according to Rouelle, 1,583; but at the temperature of 60°, Mr Kirwan could not procure it stronger than 1,5543.

Taking this acid for the standard, Mr Kirwan has calculated how much of it exists in nitric acid of inferior density. His determination may be seen in the following Table, which was formed precisely in the same manner as that formerly given of the strength of sulphuric acid.

100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid
1,5543	100	1,4018	70	1,2586	44
1,5295	95	1,3975	69	1,2525	43
1,5183	94	1,3925	68	1,2464	42
1,5070	93	1,3875	67	1,2419	41
1,4957	92	1,3825	66	1,2374	40
1,4844	91	1,3775	65	1,2291	39
1,4731	90	1,3721	64	1,2209	38
1,4719	89	1,3671	63	1,2180	37
1,4707	88	1,3621	62	1,2152	36
1,4695	87	1,3571	61	1,2033	35
1,4683	86	1,3521	60	1,2015	34
1,4671	85	1,3468	59	1,1963	33
1,4640	84	1,3417	58	1,1911	32
1,4611	83	1,3366	57	1,1845	31
1,4582	82	1,3315	56	1,1779	30
1,4553	81	1,3264	55	1,1704	29
1,4524	80	1,3212	54	1,1639	28
1,4471	79	1,3160	53	1,1581	27
1,4422	78	1,3108	52	1,1524	26
1,4373	77	1,3056	51	1,1421	25
1,4324	76	1,3004	50	1,1319	24
1,4275	75	1,2911	49	1,1284	23
1,4222	74	1,2812	48	1,1241	22
1,4171	73	1,2795	47	1,1165	21
1,4120	72	1,2779	46	1,1111	20
1,4069	71	1,2687	45	1,1040	19

Nitric Acid.

Now, how much water does nitric acid contain, the density of which is 1,5543?

Mr Kirwan dried a quantity of crystallized carbonate of soda in a red heat, and dissolved it in water, in such a proportion, that 367 grains of the solution contained 50,05 of alkali. He saturated 367 grains of this solution with 147 grains of nitric acid, the specific gravity of which was 1,2754, and which, therefore, by the preceding table, contained 45,7 per cent. of acid standard. The carbonic acid driven off amounted to 14 grains. On adding 939 grains of water, the specific gravity of the solution, at the temperature of 58,5°, was 1,0401. By comparing this with a solution of nitrat of soda, of the same density, precisely in the manner described formerly under sulphuric acid, he found, that the salt contained in it amounted to $\frac{1}{16,901}$ of the whole. There

was an excess of acid of about two grains. The weight of the whole was 1439 grains: The quantity of salt, consequently, was $\frac{1439}{16,901} = 85,142$ grains. The quantity of alkali was 50,05—14 = 36,05. The quantity of standard acid employed was 66,7. The whole of which amounted to 102,75 grains; but as only 85,142 grains entered into the composition of the salt, the remaining 17,608 must have been pure water mixed with the nitric acid. But if 66,7 of standard acid contain 17,608 of water, 100 parts of the same acid must contain 26,38*.

One hundred parts of standard nitric acid, therefore, is composed of 73,62 parts of pure nitric acid and 26,38 of water. But as Mr Kirwan has not proved that nitrat of soda contains no water, perhaps the proportion

* Phil. Transf. 1788.

410 Its properties.

411 Its strength at different specific gravities.

412 Quantity of real acid contained in concentrated nitric acid.

* Ibid. Transf. iv.

Nitric
Acid.413
Its action
on other
bodies,

of water may be greater. He has rendered it probable, however, that nitrat of soda contains very little water.

Nitric acid is decomposed by a great variety of substances. When poured upon oils, it sets them on fire. This is occasioned by a decomposition both of the acid and oil. The oxygen of the acid combines with the carbon and with the hydrogen of the oils, and at the same time lets go a quantity of caloric. Hence we see that the oxygen which enters into the composition of the nitric acid still contains a great deal of caloric; a fact which is confirmed by a great number of other phenomena. The combustion of oils by this acid was first taken notice of by Borrichius and Slare; but it is probable that Homberg communicated it to Slare. In order to set fire to the fixed oils, it must be mixed with some sulphuric acid; the reason of which seems to be, that these oils contain *water*, which must be previously removed. The sulphuric acid combines with this water, and allows the nitric acid, or rather the oil and nitric acid together, to act. The drying oils do not require any sulphuric acid: they have been boiled, and consequently deprived of all moisture. It sets fire also to charcoal, provided it be perfectly dry. This fact was first observed by Proust, and afterwards confirmed by the Dijon academicians. It sets fire also to zinc, bismuth, and tin, if it be poured on them in fusion, and to filings of iron, if they be perfectly dry*. In all these cases the acid is decomposed. Sulphurated hydrogen gas also takes fire, and burns with a strong flame by means of this acid †.

* Proust,
Dijon Aca-
demicians,
and Cor-
nette.

† Tromsdorff.

It is capable of oxidating all the metals except gold, platinum (x), and titanium. It appears, from the experiments of Scheffer, Bergman, Sage, and Tillet, that nitric acid is capable of dissolving (and consequently of oxidating) a very minute quantity even of gold.

414
Its combi-
nations,

Nitric acid combines with alkalies, alkaline earths, alumina, and jargonina, and with the oxides of metals, and forms compounds which are called *nitrats*. It does not act upon silica nor adamanta.

415
And affini-
ties.

The order of its affinities is as follows:

Barytes,
Potash,
Soda,
Strontites †,
Lime,
Magnesia,
Ammonia,
Alumina,
Jargonina ‡?
Metallic oxides, in the same order
as for sulphuric acid.
Water.

‡ Dr Hope.

§ Vauquelin,
Ann. de
Chim. xxii.
208.

SECT. IV. Of Nitrous Acid.

Nitrous
Acid,416
Component
parts of
nitrous a-
cid.

If oxygen gas be mixed with nitrous gas, a quantity of red fumes appear, which are readily absorbed by water. These red fumes are *nitrous acid*.

If a glass vessel containing nitric acid be inverted into another vessel containing the same acid, and exposed to the light, the inverted glass will become partly full of oxygen gas, and at the same time part of the nitric acid is converted into nitrous acid*. It follows, from this experiment, that nitrous acid contains less oxygen than nitric acid. Lavoisier has calculated, that it contains somewhat less than three parts of oxygen to one of azot.

417
Its proper-
ties.

Nitrous acid is of a brown or red colour, exceedingly volatile, and emitting a very suffocating and scarcely tolerable odour. When to this acid, concentrated, a fourth part by weight of water is added, the colour is changed from red to a fine green; and when equal parts of water are added, it becomes blue †. Dr Priestley observed, that water impregnated with this acid in the state of vapour became first blue, then green, and lastly yellow. A green nitrous acid became orange-coloured while hot, and retained a yellow tinge when cold. A blue acid became yellow on being heated in a tube hermetically sealed. An orange-coloured acid, by long keeping, became green, and afterwards of a deep blue; and when exposed to air, resumed its original colour. These colours seem to depend upon the concentration of the acid.

† Bergman.

Dr Priestley found that water absorbed great quantities of this acid in the state of vapour; and that when saturated, its bulk was increased one-third.

In the state of vapour, it is absorbed rapidly by oils. Whale oil, by absorbing it, became green, thick, and heavier. It gradually decomposed the acid, retained the oxygen, and emitted the azot in the state of gas ‡.

‡ Priestley,
iii. 111.

It is absorbed by sulphuric acid, but seemingly without producing any change; for when water is poured into the mixture, the heat produced expels it in the usual form of red fumes §. The only singular circumstance attending this impregnation is, that it disposes the sulphuric acid to crystallize ||. This fact, first observed by Dr Priestley in 1777 (v), was afterwards confirmed by Mr Cornette.

Nitrous acid appears capable of combining with most of the bodies with which nitric acid unites. The salts which it forms are called *nitrites*.

Its affinities have never been accurately examined. Bergman supposes them the same with those of nitric acid.

Of

(x) Nitre, however, acts upon platinum, as Mr Tennant has proved. *Phil. Trans.* 1797. Morveau had made the same observation in the *Elemens de Chimie de l'Academie de Dijon*.

(v) Bernhardt, however, relates, in 1765, that once, when he was distilling a mixture of ten pounds of nitre with an equal quantity of calcined vitriol, which he had put into a retort, to which was fitted an adapter between the retort and the receiver, which contained a quantity of water—he observed a considerable quantity of a white crystalline salt formed in the adapter, while the liquid acid passed as usual into the receiver. This salt was very volatile, smoked strongly when it was exposed to the air, and exhaled a red vapour; it burnt, to a black coal, wood, feathers, or linen, as sulphuric acid does; and where a piece of it fell, it evaporated in form of a blood red vapour, till the whole of it disappeared. Half an ounce of these crystals dissolved in water with spouting and hissing, like that of a red-hot iron dipped in water, and formed a green nitrous acid. Some of this salt being put into a bottle, which was not well stopped, entirely vanished. These crystals were evidently the same with Dr Priestley's. See *Keir's Dictionary*.

Of Nitrous Gas.

Nitrous Gas.
418
Discovery of nitrous gas.

NITROUS gas was first obtained by Dr Hales, but its properties were discovered by Dr Priestley. It may be procured by dissolving metals in nitric or nitrous acid, and catching the product by means of a pneumatic apparatus.

As nitrous acid is formed by combining nitrous gas and oxygen, it is evident that nitrous gas contains less oxygen than nitrous acid. According to Lavoisier, it is composed of two parts of oxygen and one of azot.

419
Its properties.

Nitrous gas is elastic, and invisible like common air. It extinguishes light, and instantly kills all those animals that are obliged to breathe it. Its specific gravity, according to Mr Kirwan, is 0,001458*.

* On Pblongiffon, p. 28.

Dr Priestley found that water was capable of absorbing about one-tenth of nitrous gas, and that by the absorption it acquired an astringent taste †. Water parts with all the nitrous gas it has imbibed on being frozen †.

† Priestley, i. 365.
† Ibid. p. 407.

Neither phosphorus nor sulphur seem capable of decomposing nitrous gas.

Mr Linck, professor at Rostoc, found, that three parts of nitrous gas and two of hydrogen gas, obtained by sulphuric acid and iron, are scarcely, or not at all, diminished when exposed to day-light over water. Common air is not more diminished by this admixture kept a long time: but the mixture itself of these two gases is diminished by the addition of new portions of nitrous gas. Mr Linck concludes, from this observation, that part of the oxygen of the nitrous gas combined with the hydrogen and formed water, and that the remaining oxygen and azot formed a mixture similar to the air of the atmosphere. Mr Vauquelin had previously made the same observation. The affinity of hydrogen, therefore, for oxygen is greater than that of azot §.

§ Nicholson's Jour. ii. 72.

Oils imbibe nitrous gas with avidity, and decompose it.

Nitric acid absorbs a vast quantity of it, and is by that means converted into nitrous acid.—Sulphuric acid also absorbs it.

The most important property of nitrous gas is that of combining instantly with oxygen gas, and forming nitrous acid, which is instantly absorbed by water. This property induced Dr Priestley to use nitrous gas as a test of the purity of common air. He mixed together equal bulks of these substances, and judged of the purity of the air by the diminution of bulk. The apparatus used for this purpose, which consists of a graduated tube, has been called a *eudiometer*. This eudiometer has been greatly improved by Fontana, but it is still liable to uncertainty in its application. Perhaps the best eudiometer is sulphuret of potash, which, as Morveau has discovered, absorbs, on the application of heat, the whole oxygen in a given bulk of air almost instantaneously.

Dr Priestley found that nitrous gas was decomposed by passing electric explosions through it.

Let us now consider in what manner oxygen and azot are combined in the three substances which have been just described.

420
The eudiometer.

It can hardly be conceived that azot is capable of combining with three different proportions of oxygen, and of being saturated with each: it is surely much more probable, that in nitrous gas the oxygen and azot saturate each other directly and completely; that nitrous acid is composed of nitrous gas and oxygen, and

421
Manner in which azot and oxygen are combined.

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nitric acid of nitrous acid and oxygen. And this supposition is confirmed by considering that the strength of affinity by which the oxygen is retained in each of these substances is very different. Some substances, as light, are capable of decomposing nitric acid, by seizing some of its oxygen, and of converting it into nitrous acid; but they have no effect whatever upon nitrous acid or nitrous gas. Others, as bismuth, copper, phosphorus, and sulphur, are capable of decomposing both nitric and nitrous acids, but are incapable of altering nitrous gas: And others, again, as carbon, zinc, and iron, are capable of decomposing all the three. Every body which is capable of decomposing nitrous acid is capable also of decomposing nitric acid; and every body that decomposes nitrous gas is capable also of decomposing the other two. But the reverse of this is not true. The affinity of oxygen, then, for azot, nitrous gas, and nitrous acid, is different: oxygen has a stronger affinity for azot than it has for nitrous gas, and a stronger affinity for nitrous gas than for nitrous acid. But if all these bodies were direct combinations of azot and oxygen, how could this difference of affinity take place? Is it reasonable to suppose that a substance has a stronger affinity for one proportion of any other body than for another proportion? or that, if such a difference existed, the strongest affinity should not always prevail? Mix together nitric acid and nitrous gas in proper proportions, and the whole mixture is converted into nitrous acid: but mix nitrous and nitric acids together, and no change whatever is produced. In the first case, is it not evident that the affinity of nitrous gas for oxygen is greater than that of nitrous acid; that therefore it decomposes the nitric acid, deprives it of oxygen, and leaves it in the state of nitrous acid? But, in the second case, no change can take place, because nitric acid is composed of nitrous acid and oxygen; and it would be absurd to suppose, that *nitrous acid* has a stronger affinity for oxygen than *nitrous acid* has. But were azot and oxygen capable of uniting in various proportions, why should not a mixture of nitric and nitrous acids, or of nitrous gas and nitrous acid, form new substances? And why are the only substances which appear in decompositions nitrous acid and nitrous gas? Surely these reasons are sufficient to shew us, that these bodies are combined in the following manner:

Azot and	}	form nitrous gas;
Oxygen		
Nitrous gas and oxygen	}	form nitrous acid;
Nitrous acid and oxygen		
	}	form nitric acid.

Perhaps there may be even more links in the chain than we are aware of. The dephlogisticated nitrous air of Dr Priestley, which Dieman and Van Troostwyck have lately proved to be composed of 37 parts of oxygen and 63 of azot, and of which little more is known than that it supports flame, is noxious to animals, absorbed by water, and only obtained by means of substances capable of decomposing nitrous gas—perhaps this *air* is composed directly of oxygen and azot, nitrous gas of this air and oxygen, and so on. There may be even links still farther back than that.

SECT. V. Of Muriatic Acid.

MURIATIC acid appears to have been known to Basil Valentine; but Glauber was the first who extracted it from

Muriatic Acid.

422
Discovery of muriatic acid.

Muriatic Acid. from common salt by means of sulphuric acid. Common salt is composed of muriatic acid and soda, for which last substance sulphuric acid has a stronger affinity. This acid was first called *spirit of salt*, afterwards

* From *marine acid*, and now, pretty generally, *muriatic acid* *.

It is sometimes prepared by mixing one part of common salt with seven or eight parts of clay, and distilling the mixture. The clay, in this instance, is supposed to act chiefly by means of the sulphuric acid which it always contains (z): But this subject still requires farther elucidation. By these processes, muriatic acid is obtained dissolved in water. Dr Priestley discovered, that by applying heat to this solution, and receiving the product in vessels filled with mercury, a gas was procured; which gas is muriatic acid in a state of purity.

423
Its properties. Muriatic acid gas is invisible and elastic, like common air. It destroys life and extinguishes flame. A candle, just before it goes out in it, burns with a beautiful green, or rather light blue flame; and the same flame appears when it is first lighted again †.

† Priestley, ii. 293. The specific gravity of muriatic acid in the state of gas is, according to Mr Kirwan ‡, 0,002315, which is nearly double that of common air.

‡ Irish Transf. iv. Water absorbs this gas with avidity. Ten grains of water are capable of absorbing ten grains of the gas. The solution thus obtained occupies the space of 13,3 grains of water nearly. Hence its specific gravity is 1,500, and the density of the pure muriatic acid in it is 3,03 § (A).

§ Kirwan, Irish Transf. vol. iv. As muriatic acid can only be used conveniently when dissolved in water, it is of much consequence to know how much pure acid is contained in a given quantity of liquid muriatic acid of any particular density.

424
Quantity of it contained in acids of various densities. Now the specific gravity of the purest muriatic acid that can easily be procured and preserved, is 1,196; it would be needless, therefore, to examine the purity of any muriatic acid of superior density. Mr Kirwan calculated that muriatic acid, of the density 1,196, contains $\frac{49}{100}$ parts of acid of the density 1,500, which he took for the standard; then, by means of experiments, he formed the following Table:

100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid	100 parts, at the specific gravity	Contain of standard acid
1,196	49	1,147	37	1,1036	26
1,191	48	1,1414	36	1,0984	25
1,187	47	1,1396	35	1,0942	24
1,183	46	1,1358	34	1,0910	23
1,179	45	1,1320	33	1,0868	22
1,175	44	1,1282	32	1,0826	21
1,171	43	1,1244	31	1,0784	20
1,167	42	1,1206	30	1,0742	19
1,163	41	1,1168	29	1,0630	16
1,159	40	1,1120	28	1,0345	10
1,155	39	1,1078	27	1,0169	5
1,151	38				

Muriatic acid (for this solution of the acid in water

is always called by that name) is generally of a pale yellow colour, owing, as Dr Priestley supposed, to some earthy matter dissolved in it; but much more probably to its having absorbed a quantity of oxygen, for which it has a strong affinity. Indeed, that this is the cause appears evidently from Dr Priestley's own observations; for it was destroyed only by those bodies which had a stronger affinity for oxygen. It is very volatile, as might be expected, constantly emitting white fumes of a peculiar and unpleasant odour.

Muriatic acid is capable, by the assistance of heat, of oxidating the following metals: Iron, tin, lead, zinc, bismuth, cobalt, nickel, manganese, antimony, arsenic. Several of these, as iron, for instance, it oxidates even without the assistance of heat.

At a boiling heat, it oxidates silver and copper. It has no action on gold, platinum, mercury, tungsten, molybdenum, tellurium, titanium. Its action on uranium has not been tried.

In the state of gas, it appears to decompose alcohol and oils by its affinity for water *.

It is capable of dissolving a little sulphat and fluat † of lime, and arseniat of mercury.

It combines with the alkalies, alkaline earths, alumina, and jargonia, and with most of the metallic oxides, and forms neutral salts, known by the name of *muriats*.

Morveau first shewed, that this acid, in the state of gas, neutralized putrid miasmata, and by that means destroyed their bad effects. In 1773, the cathedral of Dijon was so infected by putrid exhalations, that it was deserted, after several unsuccessful attempts to purify it. Application was made to Mr Morveau to see whether he knew any method of destroying these exhalations. He poured two pounds of sulphuric acid on six pounds of common salt, contained in a glass capsule, which had been placed on a few live coals in the middle of the church. He withdrew precipitately, and shut all the doors. The muriatic acid gas soon filled the whole cathedral, and could even be perceived at the door. After 12 hours, the doors were thrown open, and a current of air made to pass through to remove the gas. This destroyed completely every putrid odour †.

The affinities of muriatic acid are as follow:

- Barytes,
- Potash,
- Soda,
- Strontites §,
- Lime,
- Magnesia,
- Ammonia,
- Alumina,
- Jargonia ||,
- Metallic oxides as in sulphuric acid,
- Water.

SECT. VI. Of Oxy-muriatic Acid.

PUT into a glass retort one part of the black oxide of manganese and three parts of muriatic acid; place it in a sand-bath in such a manner that the liquor which rises up into the neck of the retort may fall back again into

(z) Morveau has shewn, that even alumina contains sulphuric acid, provided a precipitation, on adding muriatic acid, be a sufficient test.

(A) For let D = the density of a mixture; m the weight of the denser ingredient; d its density; l the weight of an

Oxy-muriatic Acid.

425
Its action on other bodies.

* Priestley, ii. 281.
† See sect. ix.

426
Destroys putrid miasmata.

‡ Jour. de Phys. i. 436.
427
Its affinities.

§ Dr Hops.

|| Vauquelin, Ann. de Chim. xxii. 208.

428
Discovery and preparation of oxy-muriatic acid.

Part II.

Oxy-muriatic Acid. into the vessel; and apply a small receiver, with a little water in it, luted to the retort merely by a fillet of brown paper. In about a quarter of an hour the receiver will appear filled with a yellow-coloured gas; it is then to be removed, and others applied successively till the operation be finished.

This gas is oxy-muriatic acid, first discovered by Scheele, while he was making experiments on manganese, and called by him *dephlogisticated muriatic acid*, because he thought it muriatic acid deprived of phlogiston. The French chemists called it *oxygenated muriatic acid*, which Dr Pearson contracted into *oxy-muriatic acid*; and this last name we have adopted, because it is shorter and equally distinct.

429
Its composition.

The true theory of the formation and composition of this acid, which was first given by Berthollet, will appear from the following facts: The black oxide of manganese is, during the process, converted into white oxide, and must therefore have given out a quantity of oxygen. When oxy-muriatic acid dissolved in water is presented to the light in a vessel half empty, oxygen gas is disengaged and floats above, and the acid is converted into common muriatic acid: Consequently oxy-muriatic acid is composed of muriatic acid and oxygen. Black oxide of manganese is composed of white oxide and oxygen; muriatic acid has a stronger affinity for oxygen than the white oxide; during the distillation the black oxide is decomposed, the oxygen combines with muriatic acid, and the product is oxy-muriatic acid gas.

430
Its properties.

Oxy-muriatic acid gas is of a yellow colour. It supports flame, but cannot be breathed without proving noxious. The death of the ingenious and industrious Pelletier, to whom we have so often referred, was occasioned by his attempting to respire it. A consumption was the consequence of this attempt, which, in a short time, proved fatal.

It does not unite readily with water. Scheele found, that after standing 12 hours over water, $\frac{4}{5}$ ths of the gas were absorbed: the remainder was common air, which no doubt had been contained in the vessel before the operation. Berthollet surrounded several bottles containing it with ice: as soon as the water in these bottles was saturated, the gas became concrete, and sunk to the bottom of the vessels; but the smallest heat made it rise in bubbles, and endeavour to escape in the form of gas*. Westrum observed that it became solid when exposed in large vessels to the temperature of 40°; and that then it exhibited a kind of crystallization †. The specific gravity of water saturated with this gas, at the

* Journ. de Phys. 1785.
† Journ. de Physique, xxxvii. 382.

temperature of 43°, is 1,003*. Water impregnated with it has not an acid, but an austere taste †, unlike that of other acids.

It renders vegetable colours *white*, and not red, as other acids do; and the colour thus destroyed can neither be restored by acids nor alkalies. It has the same effects on yellow wax. If the quantity of vegetable colours to which it is applied be sufficiently great, it is found reduced to the state of common muriatic acid. Hence it is evident, that it destroys these colours by communicating oxygen. This property has rendered oxy-muriatic acid a very important article in bleaching.

Nitrous gas, hydrogen, sulphur, sulphurous acid, and phosphorus, decompose this acid, by depriving it of its oxygen, and leaving the muriatic acid in a separate state. Phosphorus, however, does not produce this effect so readily, except when assisted by heat*.

When muriatic acid is mixed with nitric acid, the compound has precisely the smell and the qualities of oxy-muriatic. It can scarcely be doubted, therefore, that as far as it acts as an acid, different from the muriatic and the nitric, it is nothing else but oxy-muriatic acid.

This mixture of the two acids was formerly called *aqua regia*; but at present it is called by the French chemists *nitro-muriatic acid*. It is first mentioned by Isaac the Hollander, and seems to have been known before the muriatic acid itself. It was prepared by pouring nitric acid on common salt. The nitric acid decomposes the salt, and part of it unites with the muriatic acid thus set at liberty.

Oxy-muriatic acid oxidates all the metals (except, perhaps, titanium) without the assistance of heat.

It decomposes red sulphuret of mercury, or cinnabar, which neither sulphuric nor nitric acid is able to accomplish †.

All the substances placed before muriatic acid in the table of the affinities of oxygen, are capable of decomposing this acid. Many of them, when plunged into it while in the state of gas, actually take fire. Westrum observed, for instance, that when pieces of wood were plunged into this gas, they took fire; that arsenic burned with a blue and green flame; bismuth, with a lively bluish flame; nickel, with a white flame, bordering on yellow; cobalt, with a white flame, approaching to blue; zinc, with a lively white flame; tin, with a feeble bluish flame; lead, with a sparkling white flame; copper and iron, with a red flame: that powdered charcoal took fire in it at the temperature of 90°, and that ammonia produced with it a loud detonation ††.

* Morveau, Encyc. Method. Chimie, i. 251.
† 431 Nitro-muriatic acid.

432 Its action on other bodies.

§ Bergman.

|| Journ. de Physique, xxxvii. 385.

R r 2

With

an equal bulk of water; and m' , d' , and l' , the same elements of the rarer: Then $D = \frac{m + m'}{l + l'}$. In the above case, $m + m' = 20$, and $l + l' = 13,3$. Then $D = \frac{20}{13,3} = 1,5$. Now to find the specific gravity of the condensed muriatic acid gas, we have from the above equation $l = \frac{m + m' - l' D}{D} = \frac{5}{1,5} = 3,3$; and $d = \frac{m}{l} = \frac{10}{3,3} = 3,03$. See *Irish Transactions*, vol. iv.

This calculation, however, is formed upon the supposition that the water suffers no condensation at all—a supposition certainly contradicted by every analogy, and which, as Mr Keir has shewn, the experiments mentioned in Mr Kirwan's first paper are insufficient to prove.

Oxy-muriatic Acid. With alkalies, earths, and metallic oxides, it is capable of combining and forming neutral salts, which have been called *oxy-muriats*.

⁴³³ Its affinities. The affinities of this acid, according to Lavoisier, are as follows :

Alumina,
Jargonite * ?
Ammonia,
Oxide of antimony,
—— silver,
—— arsenic,
Barytes,
Strontites ?
Oxide of bismuth,
Lime,
Oxide of cobalt,
—— copper,
—— tin,
—— iron,
Magnesia (b),
Oxide of manganese,
—— mercury,
—— molybdenum,
—— nickel,
—— gold,
—— platinum,
—— lead,
Potash,
Soda,
Oxide of tungsten,
—— zinc (c).

* *Vauquelin, Ann. de Chim. xxii. 208.*

⁴³⁴ Of the component parts of muriatic acid.

The component parts of muriatic acid are still imperfectly known. Dr Girtanner pretended, about the year 1790, that he had decomposed it; and that it consisted of hydrogen combined with a greater proportion of oxygen than enters into the composition of water. He passed electrical explosions through muriatic acid, and obtained a quantity of oxygen and hydrogen gas. But a repetition of these experiments shewed, that the gases were owing, not to the decomposition of the acid, but to that of the water with which the acid was combined.

The experiments of Mr Lambe (d) have lately opened a new and unexpected path, which seems to lead directly to the discovery of the component parts of this acid. He found, that when iron was acted upon by sulphurated hydrogen gas, a substance was produced which possessed all the properties of oxy-muriatic of iron (oxy-muriatic acid combined with iron). The sulphurated hydrogen gas which he used was obtained from sulphuret of iron, formed by fusing equal parts of iron and flowers of sulphur; and it was extricated by diluted sulphuric acid. In a solution of this gas in distilled water, he digested iron filings, previously purified by repeated washings with distilled water. The bottle was filled with the solution, and corked. The iron was presently acted upon; numerous bubbles arose, which drove the cork

out of the bottle; they were strongly inflammable, and probably, therefore, pure hydrogen gas. The liquor gradually lost its odour of sulphurated hydrogen gas, and after some days smelled very much like stagnant rain-water. As the bubbles ceased to be produced, it recovered its transparency. On evaporating a small quantity of this solution in a watch-glass to dryness, a bitter deliquescent salt was left behind. On this salt a little sulphuric acid was dropped, and paper moistened with ammonia was held over the glass; white vapours were immediately formed over the glass; and consequently some volatile acid was separated by the sulphuric acid. Mr Lambe evaporated about eight ounce measures of the same liquor, and, as before, dropped a little sulphuric acid on the residuum; a strong effervescence was excited, very pungent acid fumes arose, which, from their smell, were readily known to be muriatic. The same truth was established beyond a doubt, by holding a bit of paper moistened with water, which made the vapours visible in the form of a grey smoke; a distinguishing characteristic, as Bergman has observed, of the muriatic acid.—When manganese and mercury were dissolved in sulphurated hydrogen gas, the salts formed gave the same unequivocal marks of the presence of muriatic acid *.

* *Lambe, ibid.*

Shall we conclude from these facts, that the basis of muriatic acid is sulphurated hydrogen; that muriatic acid is sulphurated hydrogen combined with oxygen; that this combination takes place during the solution of the iron; and that the escape of hydrogen is owing to the decomposition of the water?

SECT. VII. Phosphoric Acid.

PHOSPHORUS is capable of forming combinations with two different quantities of oxygen; with the larger it forms phosphoric; and with the smaller phosphorous acid.

⁴³⁵ Disc. very of phosphorus.

Phosphoric acid was unknown till after the discovery of phosphorus. Boyle is perhaps the first person who mentions it: he discovered it by allowing phosphorus to burn slowly in common air. But Margraf was the first person who examined its properties, and discovered it to be a peculiar acid.

It may be procured by exposing phosphorus to a moderate heat: the phosphorus takes fire, combines with oxygen, and is converted into an acid.

It may also be prepared by exposing phosphorus during some weeks to the ordinary temperature of the atmosphere, even in winter; when the phosphorus undergoes a slow combustion, and is gradually changed into a liquid acid. For this purpose, it is usual to put small pieces of phosphorus on the inclined side of a glass funnel, through which the liquor which is formed drops into the bottle placed to receive it. From one ounce of phosphorus about three ounces of acid liquor may be thus prepared, called *phosphoric acid by deliquescence*.

⁴³⁶ Method of preparing it

Scheele has contrived another mode of obtaining the phosphoric

(b) According to Trommsdorf, oxy-muriatic acid is incapable of combining with magnesia. *Ann. de Chim. xxii. 218.*

(c) This is the order of the affinities of nitro-muriatic acid. Many facts (some of which shall appear afterwards) concur to prove that the affinities of the oxy-muriatic acid are the same, and indeed that they are the same acids.

(d) Analysis of the waters of two mineral springs at Lemington Priors. *Manchester Memoirs, vol. V. part 1st.*

Part II.

Phosphoric Acid.

* On Fire, § lxxvii.
† Mem. Acad. 1780.

phosphoric acid from phosphorus without combustion, by the mere action of the nitric acid on phosphorus*. Mr Lavoisier has repeated and described this process †. He put two pounds of nitric acid, the specific gravity of which was 1,29895, into a retort, the contents of which were equal to six or seven French pints, and to which a balloon was fitted. Having placed this retort in a sand-bath, and brought the heat of the acid contained in it to 133¼ deg. he added successively small quantities of phosphorus, about 10 or 12 grains at a time, until he had dissolved 2¼ oz. At first the effervescence was great, but at last he was obliged to apply heat to effect the solution. The operation lasted 17 or 18 hours. A good deal of nitrous acid had passed into the receiver. He then poured the contents of the retort into a smaller retort, and evaporated by means of a stronger heat, until the phosphoric acid began to distil in white vapours. The remaining acid was so thick that he could not pour it out of the retort, and therefore could not ascertain its quantity; but he supposes it might be 8 or 9 ounces, in which he thinks there were about 2½ ounces of phosphorus; the remaining ¼ ounce being supposed to have evaporated. The quantity of oxygen imbibed he reckons at 3½ ounces, and the quantity of water at about 2 ounces.

Lavoisier computes that phosphoric acid contains 100 parts of phosphorus and 154 of oxygen.

The colour of this acid is white; it has no smell, has an acid taste; but is not corrosive (E).

It is exceedingly fixed. When exposed to the fire in a matrass with a long neck, it loses at first the greater part of its water; then an odour of garlic is felt, owing to some phosphorus, from which it is exceedingly difficult to clear it entirely; there is likewise a small quantity of the acid volatilized along with the water. The liquor then becomes thick and milky: small luminous decrepitations take place from time to time, and they continue for some time after the vessel is taken from the fire. If the matter be then put into a crucible, and placed among burning coals, it first boils violently, and gives out a vapour which tinges flame green, and is at last converted to a white transparent glass, insoluble in water.

The specific gravity of this acid in a state of dryness is 2,687 †, that of phosphoric acid by deliquescence 1,417 §. It is capable of crystallizing; its crystals are quadrangular prisms terminated by quadrangular pyramids.

Phosphoric acid obtained by deliquescence, when mixed with an equal quantity of distilled water, acquired so little heat as to raise the thermometer only one degree, as Mr Sage observed.

Mr Lavoisier raised Reaumur's thermometer from 8° to 14° or 15° by mixing phosphoric acid boiled to the consistence of a syrup, with an equal quantity of water; and from 8° to 32° or 33° when the acid was as thick as turpentine ||.

Phosphoric acid is capable of oxidating iron, tin, lead, zinc, antimony, bismuth, manganese. When fused with several of these metals, as tin, lead, iron, and zinc, it is converted into phosphorus; a proof that they have a stronger affinity for oxygen.

It does not act upon gold, platinum, silver, copper, mercury, arsenic, cobalt, nickel. It appears, however, to have some action on gold in the *dry way*, as it is called; for when fused with gold-leaf it assumes a purple colour; a proof that the gold has been oxidated.

It is capable of combining with alkalies, alkaline earths, alumina, and metallic oxides; and of forming salts known by the name of *phosphates*.

Phosphoric acid, by the assistance of heat, is capable of decomposing glass.

Its affinities are as follows:

- Lime,
- Barytes,
- Strontites*,
- Magnesia,
- Potash,
- Soda,
- Ammonia,
- Alumina,
- Jargonia †,
- Metallic oxides as in sulphuric acid,
- Water.

439
Its affinities.

* Hope, Trans. Edin. iv.

† Vauquelin, Ann. de Chim. xxii. 208.

THE PHOSPHOROUS ACID is formed when phosphorus is exposed to a slow spontaneous combustion at the temperature of the atmosphere; but it gradually absorbs more oxygen, and is converted into phosphoric acid.

Concerning phosphorous acid nothing of any consequence is at present known, except that it contains less oxygen than phosphoric acid.

SECT. VIII. Boracic Acid.

THE word *borax* first occurs in the works of Geber, an Arabian chemist of the 10th century. It is a name given to a species of white salt much used by various artists. Its use in folding metals appears to have been known to Agricola.

Borax is found mixed with other substances in Thibet. It seems to exist in some lands adjacent to lakes, from which it is extracted by water, and deposited in those lakes; whence in summer, when the water is shallow, it is extracted and carried off in large lumps. Sometimes the water in these lakes is admitted into reservoirs, at the bottom of which, when the water is exhaled by the summer's heat, this salt is found.—Hence it is carried to the East Indies, where it is in some measure purified and crystallized: in this state it comes to Europe, and is called *tinca*. In other parts of Thibet, it seems, by accounts received from China, they dig it out of the ground at the depth of about two yards, where they find it in small crystalline masses, called by the Chinese *mi poun*, *houi poun*, and *pin poun*; and the earth or ore is called *pounxa* †.

Though borax has been in common use for nearly three centuries, it was only in 1702 that Homberg, by distilling a mixture of borax and green vitriol, discovered the *boracic acid*. He called it *narcotic* or *sedative salt*, from a notion of his, that it possessed the properties indicated by these names. In his opinion, it was merely a product of the vitriol which he had used; but Lémery the Younger soon after discovered, that it could likewise be obtained from borax by means of the nitric and muriatic acids. Geoffroi afterwards discovered,

441
Borax.

† Kirwan's Mineralogy, ii. 37.

442
Discovery of boracic acid.

that

(E) We have observed, however, that when very much concentrated it destroyed the texture of vegetable substances, paper for instance, very completely.

437
Its properties.

¶ Keir's Dictionary, 438
Its action on other bod.es.

Boracic
Acid.Fluoric
Acid.

that borax contained soda: and at last Baron proved, by a number of experiments, that borax was composed of boracic acid and soda; that it might be reproduced by combining these two substances—and that therefore the boracic acid was not formed during the decomposition of borax, as former chemists had imagined, but was a peculiar substance which pre-existed in that salt.

443
Attempts
to prove
that it does
not exist in
borax;

* Journ. de
Phys. 1782.

This conclusion has been called in question by Mr Cadet *, who affirmed that it was composed of *soda, the vitrifiable earth of copper, another unknown metal, and muriatic acid*. But this assertion has never been confirmed by a single proof; Mr Cadet has only proved that boracic acid sometimes contains copper; and Beaume's experiments are sufficient to convince us that this metal is merely accidentally present, and that it is probably derived from the vessels employed in crystallizing borax: That boracic acid generally contains a little of the acid employed to separate it from the soda, with which it is combined in borax: And that crude borax contains a quantity of earth imperfectly saturated with boracic acid:—All which may be very true; but they are altogether insufficient to prove that boracic acid is not a peculiar substance, since it displays properties different from every other body.

444
And to
prove that
it is phos-
phoric acid.

Messrs Exschauquet and Struve have endeavoured, on the other hand, to prove that the phosphoric and boracic acids are the same. But their experiments merely shew that these acids resemble one another in several particulars; and though they add considerably to our knowledge of the properties of the phosphoric acid, they are quite inadequate to establish the principle which these chemists had in view; since it is not sufficient to prove the identity of the two acids, to shew us a resemblance in a few particulars, while they differ in many others. Boracic acid must therefore be considered as a distinct substance, the component parts of which are entirely unknown.

445
Method of
procuring
it.

The easiest method of procuring boracic acid is the following one: Dissolve borax in hot water, and filter the solution; then add sulphuric acid, by little and little, till the liquor be rather more than saturated. Lay it aside to cool, and a great number of small, shining, laminated crystals will form. These are the boracic acid. They are to be washed with cold water, and drained upon brown paper.

446
Its proper-
ties.

This acid has a sourish taste at first, then makes a bitterish cooling impression, and at last leaves an agreeable sweetness. Its crystals have some resemblance to spermaceti, and it has the same kind of feel.

It changes vegetable blues to red; it has no smell; but when sulphuric acid is poured on it, a transient odour of musk is produced*. The air produces no change on it.

* Reufs
De Sale Se-
dat. 1778.

According to Reufs, it is soluble in 20 parts of cold water, eight parts of warm water, and 2,5 of boiling water. According to Wenzel, 960 grains of boiling water dissolve 434 of this acid. According to Morveau, one pound of boiling water dissolves only 183 grains.

It is exceedingly fixed when not combined with water. When exposed to a violent fire it is converted into a white transparent glass; which, however, is soluble in water, and produces the acid again by evaporation.

Boracic acid is also soluble in alcohol; and alcohol containing it burns with a green flame.

† Kirwan's
Miner. ii. 4.

Its specific gravity is 1,479 †.

Paper dipped into a solution of boracic acid burns with a green flame.

Though mixed with fine powder of charcoal, it is nevertheless capable of vitrification; and with foot it melts into a black bitumen-like mass, which is, however, soluble in water, and cannot be easily calcined to ashes, but sublimes in part*.

With the assistance of a distilling heat it dissolves in oils, especially in mineral oils; and with these it yields fluid and solid products, which give a green colour to spirit of wine.

When boracic acid is rubbed with phosphorus, it does not prevent its inflammation; but an earthy yellow matter is left behind †.

It is hardly capable of oxidating or dissolving any of the metals except iron and zinc, and perhaps copper.

Boracic acid combines with alkalis, alkaline earths, and alumina, and most of the metallic oxides, and forms compounds, which are called *borats*.

Its affinities are as follows:

Lime,
Barytes,
Strontites †,
Magnesia,
Potash,
Soda,
Ammonia,
Oxide of zinc,
—— iron,
—— lead,
—— tin,
—— cobalt,
—— copper,
—— nickel,
—— mercury,
Alumina,
Jargonias ‡,
Water,
Alcohol.

† *Ibid.*
447
Its action
on other
bodies.

448
Its affini-
ties.

‡ *Dr Hefe,*
Trans. B-
din. iv.

§ *Vauqu-*
elin, Ann. de
Chim. xxii.
208.

SECT. IX. Fluoric Acid.

THE mineral called *fluor* or *fusible spar*, was not properly distinguished from other spars till Margraf published a dissertation on it in the Berlin Transactions for 1768. He first proved that it contained no sulphuric acid, as had been formerly supposed; he then attempted to decompose it, by mixing together equal quantities of this mineral and sulphuric acid, and distilling them. By this method he obtained a *white sublimate*, which he supposed to be the fluor itself volatilized by the acid. He observed, with astonishment, that the glass retort was corroded, and even pierced with holes. Nothing more was known concerning fluor till Scheele published his experiments three years after; by which he proved that it was composed chiefly of lime and a particular acid, which has been called *fluoric acid*.

To obtain it, put eight ounces of finely powdered fluor into a retort, and pour on it an equal quantity of sulphuric acid, and lute to the retort, as exactly as possible, a receiver containing eight ounces of water. Vapours immediately appear and darken the inside of the vessel: These are the acid in the state of gas. The distillation is to be conducted with a very moderate heat, not only to allow the gas to condense, but also to prevent the fluor itself from subliming. After the process,

449
Discovery
of fluoric
acid.

450
Method of
obtaining
it.

Fluoric Acid.

cess, a crust of white earth is found in the receiver, which has all the properties of silica.

Scheele supposed that the silica produced was formed of fluoric acid and water, and Bergman adopted the same opinion. But Wiegleb and Buccholz shewed, that the quantity of silica was exactly equal to what the retort lost in weight; and Meyer completed the proof that it was derived from the glass, by the following experiment: He put into each of three equal cylindrical tin vessels a mixture of three oz. of sulphuric acid and one oz. of fluor, which had been pulverized in a mortar of metal. Into the first he put one oz. of pounded glass; into the second, the same quantity of quartz in powder; and into the third, nothing. Above each of the vessels he hung a sponge moistened with water; and having covered them, he exposed them to a moderate heat. The sponge in the first cylinder was covered with the crust in half an hour; the sponge in the second in two hours; but no crust was formed in the third, though it was exposed several days. In consequence of this decisive experiment, Bergman gave up his opinion, and wrote an account of Meyer's experiment to Morveau, who was employed in translating his works, to enable him to correct the mistake in his notes.

451 Attempts to disprove its existence.

Soon after the discovery of this acid, difficulties and doubts concerning its existence as a peculiar acid were started by some French chemists, disguised under the name of Boulanger, and afterwards by Mr Achard and Mr Monnet. To remove these objections, Mr Scheele instituted and published a new set of experiments; which not only completely established the peculiar nature of the fluoric acid, but once more displayed the unrivalled abilities of the illustrious discoverer. These important particulars we pass over thus slightly, because they have been partly treated of already in the article CHEMISTRY, *Encycl.* One experiment, however, we cannot omit, because it is sufficient of itself to destroy almost all the objections of his antagonists, which consisted in attempting to prove, that the fluoric acid was merely a modification of the acid employed to extract it. We shall give it in Mr Scheele's own words.

452 Retuted by Scheele,

"I melted together (says he) in a crucible two ounces of finely pulverized fluor spar with four ounces of potash. As soon as they were melted, I poured out the mass, rubbed it, when it was become cold, to a powder, and extracted the alkali from it again by lixiviation with water. I evaporated the lixivium to dryness; and threw away the remaining undissolved powder (which was only one of the component parts of the fluor, and which dissolved readily, and with effervescence, in acids) from its solution, in which it may be precipitated by sulphuric acid in the form of selenite (sulphat of lime). Upon a little of the dried alkali, put into a small retort, I poured some sulphuric acid, fitted to it a receiver containing some water; and even before the retort was become hot, I observed this water to be covered over with a pellicle of siliceous earth: a certain proof that the alkali had extracted the acid from the fluor during its exposure to the fire with it. Should Mr Achard, agreeably to the opinion which he has adopt-

ed, conclude from this experiment, that the alkali separated the volatile earth from the fluor (F); still he must certainly allow this earth of his to be of an acid nature, since the alkali is capable of disengaging it from the calcareous earth.—The remaining portion of the dried alkali I dissolved again in water, and saturated the superfluous alkali with pure nitric acid. After expelling from this saturated solution, by means of heat, the carbonic acid gas, which in such cases is always retained in the liquor, I dropped some of it into lime-water; whereupon I obtained a white precipitate, which was a regenerated fluor. I now dissolved some oxide of lead in vinegar, and continued to add to the ley, which had been saturated with nitric acid, as much of this solution as was requisite, till all precipitation ceased. Thus I transferred the fluor acid from the alkali to the oxide of lead. After washing the precipitate in cold water, and drying it, I dropped upon a small quantity of it a few drops of sulphuric acid; a frothing up immediately ensued, accompanied with an extrication of fluor acid vapours. But perhaps, in this case, the volatile earth of fluor unites with the sulphuric acid, and converts this fixed, or almost fixed acid into acid gas. I can easily make allowance to Dr Priestley for being inclined to draw such a conclusion, since this celebrated philosopher does not pretend to be a chemist (G). Being desirous of seeing whether heat alone was capable of expelling this acid from the oxide of lead, I put a little of this fluorated oxide into a small retort, the receiver to which contained some water. The oxide was melted; but I could not perceive any acid. The bottom of the retort was moreover quite corroded and dissolved, so that the whole ran into the fire. Thus the oxide of lead retains this acid in the fire, and will not part with it, unless the oxide is combined with some other substance. I therefore rubbed the remainder of my fluorated oxide of lead with an equal quantity of charcoal powder, and distilled the mixture in an open fire in a small glass retort, to which was adapted a receiver containing some water. As soon as the reduction of the oxide of lead took place, the neck of the retort became incrustated with a white sublimate, and a siliceous pellicle appeared upon the water. The sublimate had a sour taste, because the siliceous earth of which it consists is penetrated with fluoric acid; and the acid water in the receiver let fall, on the addition of volatile alkali, a siliceous earth *."

Sorry are we to add, that since the death of this admirable man, to use the words of Mr Kirwan †, a man as eminent in the chemical as Newton in the mathematical branch of natural philosophy, Mr Monnet ‡ has thought proper to renew his attacks in a style of haughtiness and acrimony that inspires infinite disgust. The falacy of his reasoning is sufficiently exposed by Mr Le-onhardi, in the 6th volume of his late learned edition of Macquer's Dictionary.

* *Crell's Journal*, i. 222. Eng. Transl. † *Mineralogy*, i. 126. ‡ *Journ. de Phys.* xxx. 253. 453 And Leonhardi. 454 Its properties.

Fluoric acid may be obtained in the form of gas, by applying a moderate heat to sulphuric acid and fluor spar, and receiving the product over mercury.

This gas is the acid in a state of purity. It is invisible and elastic like air; it does not maintain combustion,

(F) Mr Achard affirmed that fluor was composed of a peculiar volatile earth. (G) Dr Priestley at first advanced this hypothesis, but he afterwards gave it up.

Carbonic Acid.

tion, nor can animals breathe it without death. It has a pungent smell, not unlike that of muriatic acid.

It is heavier than common air. It corrodes the skin almost instantly. It combines rapidly with water; and if it has been obtained by means of glass vessels, it deposits at the same time a quantity of silica.

Water impregnated with this gas does not freeze at a higher temperature than 23°*.

In the state of gas this acid does not act upon nitrous gas nor sulphur. Alcohol and ether absorb it, but it does not alter their qualities †.

It is capable of oxidating iron, zinc, copper, and arsenic. It does not act upon gold, platinum, silver, mercury, lead, tin, antimony, cobalt.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms compounds denominated fluats.

It is capable, as we have seen, of dissolving silica, which is insoluble in every other acid; accordingly it corrodes glass. This property has induced several ingenious men to attempt, by means of it, to engrave, or rather etch, upon glass.

The affinities of fluoric acid are as follows:

- Lime,
- Barytes,
- Strontites †,
- Magnesia,
- Potash,
- Soda,
- Ammonia,
- Oxide of zinc,
- manganese ‡,
- iron,
- lead,
- tin,
- cobalt,
- copper,
- nickel,
- arsenic,
- bismuth,
- mercury,
- silver,
- gold,
- platinum,
- Alumina,
- Jargonia || ?
- Water,
- Silica,
- Alcohol.

SECT. X. Of Carbonic Acid.

CARBONIC acid is composed of carbon and oxygen. According to Lavoisier's experiments, the proportions are 28 parts of carbon and 72 of oxygen. Mr Proust informs us that there is also a carbonous acid (H); but with this acid we are not at present acquainted, and cannot therefore describe it.

Paracelsus and Van Helmont were acquainted with the fact, that air is extricated from solid bodies during

certain processes, and the latter gave to air thus produced the name of gas. Boyle called these kinds of air artificial airs, and suspected that they might be different from the air of the atmosphere. Hales ascertained the quantity of air that could be extricated from a great variety of bodies, and shewed that it formed an essential part of their composition. Dr Black proved, that the substances then called lime, magnesia, and alkalies, are compounds, consisting of a peculiar species of air, and pure lime, magnesia, and alkali. To this species of air he gave the name of fixed air, because it existed in these bodies in a fixed state. This air or gas was afterwards investigated by Dr Priestley, and a great number of its properties ascertained. From these properties Mr Keir* first concluded that it was an acid; * Keir's and this opinion was soon confirmed by the experiments of Bergman, Fontana, &c. Dr Priestley at first suspected that this acid entered as an element into the composition of atmospheric air; and Bergman adopting the same opinion, gave it the name of aerial acid. Mr Bewdly called it mephitic acid, because it could not be respired without occasioning death; and this name was also adopted by Morveau. Mr Keir called it calcareous acid; and at last Mr Lavoisier, after discovering its composition, gave it the name of carbonic acid gas.

The opinions of chemists concerning the composition of carbonic acid have undergone as many revolutions as its name. Dr Priestley and Bergman seem at first to have considered it as an element; and several celebrated chemists maintained that it was the acidifying principle. Afterwards it was discovered that it was a compound, and that oxygen gas was one of its component parts. Upon this discovery the prevalent opinion of chemists was, that it consisted of oxygen and phlogiston; and when hydrogen and phlogiston came (according to Mr Kirwan's theory) to signify the same thing, it was of course maintained that carbonic acid was composed of oxygen and hydrogen: and though Mr Lavoisier demonstrated that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; because carbon was itself considered as a compound, into which a very great quantity of hydrogen entered. But after Mr Lavoisier had demonstrated that the weight of the carbonic acid produced was precisely equal to the carbon and oxygen employed; after Mr Cavendish had discovered that oxygen and hydrogen when combined did not form carbonic acid, but water—it was no longer possible to hesitate that this acid was composed of carbon and oxygen. Accordingly all farther dispute about it seems now at an end. At any rate, as we have already examined the objections that have been made to this conclusion, it would be improper to enter upon them here.

If any thing was still wanting to put this conclusion beyond the reach of doubt, it was to decompose carbonic acid, and thus to exhibit its component parts by analysis as well as synthesis. This has been actually done by the ingenious Mr Tennant. Into a tube of glass he introduced a bit of phosphorus and some

* Priestley, ii 362.
455
Its action on other bodies.
† Ibid.

456
Its affinities.

‡ Dr Hope.

§ Lavoisier.

|| Vauquelin, Ann. de Chim. xxii. 208.

Carbonic Acid.

458
Theories about its composition.

459
Its analysis.

457
Discovery of carbonic acid.

(H) When there are two acids having the same base, but containing different quantities of oxygen, they are distinguished by their termination. The name of that which contains most oxygen ends in *ic*, the other in *ous*. Thus sulphuric and sulphurous acids, nitric and nitrous, phosphoric and phosphorous, carbonic and carbonous.

Carbonic Acid.

some carbonat of lime. He then sealed the tube hermetically, and applied heat. Phosphat of lime was formed, and a quantity of carbon deposited. Now phosphat of lime is composed of phosphoric acid and lime; and phosphoric acid is composed of phosphorus and oxygen. The substances introduced into the tube were phosphorus, lime, and carbonic acid; and the substances found in it were phosphorus, lime, oxygen, and carbon. The carbonic acid, therefore, must have been decomposed, and it must have consisted of oxygen and carbon. This experiment was repeated by Dr Pearson, who ascertained that the weight of the oxygen and carbon were together equal to that of the carbonic acid which had been introduced; and in order to shew that it was the carbonic acid which had been decomposed, he introduced pure lime and phosphorus; and instead of obtaining phosphat of lime and carbon, he got nothing but phosphuret of lime. These experiments were also confirmed by Messrs Fourcroy, Vauquelin, Sylvestre, and Broignart (1)*.

* Ann. de Chim. xiii. 312.

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Its properties,

Carbonic acid may be obtained by pouring sulphuric acid upon chalk, and receiving the product in a pneumatic apparatus.

It is invisible and elastic like common air. It extinguishes a candle, and is unfit for respiration. It has no smell.

† Bergman, i. 9.

Its specific gravity is 0,0018 †; but this varies according to its dryness or moisture.

‡ Ibid.

It reddens the tincture of turnsole, but no other vegetable colour ‡.

Atmospheric air contains about $\frac{1}{1000}$ part of this gas (κ).

Water absorbs it by agitation, or by allowing it to remain long in contact with it. At the temperature of 41° water absorbs its own bulk of this gas. The specific gravity of water saturated with it is 1,0015. This water, at the temperature of 35°, has little taste; but if it be left a few hours in the temperature of 88°, it assumes an agreeable acidity, and a sparkling appearance §.

§ Ibid.

Ice absorbs no carbonic acid; and if water containing it be frozen, the whole separates in the act of freezing ||.

|| Priestley, i. 120.

This gas also separates from water at the boiling temperature ¶.

¶ Ibid.

Alcohol and oil of turpentine absorb double their weight of this gas; olive oil its own bulk. Ether mixes with it in the state of gas*.

* Bergman, ibid.

Phosphorus suffers no change in this gas except it contains a mixture of oxygen gas †. It has an affinity for common air. Bergman left a bottle of it uncorked, and found that in a few days it contained nothing but common air. Common air, indeed, has so strong an affinity for this gas, that it attracts it from water, as Mr Welter has observed ‡.

‡ Ann. de Chim. iii. 91.

SUPPL. VOL. I. Part I.

It is absorbed by red hot charcoal, as Morozzo and La Metherie have shewn.

It is capable of combining with alkalies, alkaline earths, and alumina, and several metallic oxides, and of forming compounds known by the name of carbonats. It has no affinity for jargonite, according to Klaproth*; but, according to Vauquelin, it has †.

Its affinities, as arranged by Bergman, are as follows:

Barytes,
Lime,
Strontites ‡,
Potash,
Soda,
Magnesia,
Alumina,
Metallic oxides as in sulphuric acid,
Oxygen gas §,
Water,
Alcohol.

Acetous Acid.
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pounds,
* Journ. de Phys. xxxvi. 186.
† Ann. de Chim. xxii. 204.
‡ 462
And affinities.
‡ Dr Hope.

§ Mr Welter.

SECT. XI. Of Acetous Acid.

Acetous acid or vinegar was known many ages before the discovery of any other acid, those only excepted which exist ready formed in vegetables. It is mentioned by Moses, and indeed seems to have been in common use among the Israelites and other eastern nations at a very early period.

The methods of procuring, purifying, and concentrating this acid, have been already given in the articles CHEMISTRY, FERMENTATION, and VINEGAR, *Encycl.* and cannot therefore be repeated in this place.

It has been ascertained beyond a doubt, that this acid is composed of carbon, hydrogen, and oxygen; but neither the manner in which these substances are combined, nor their proportions, have been accurately ascertained.

Acetous acid, as commonly prepared, is very fluid, has a pleasant smell, and an acid taste. It reddens vegetable colours. In this state it is mixed with a great proportion of water; but Mr Lowitz of Petersburg has discovered that it may be obtained in a solid crystallized form. Of this curious and instructive process we shall transcribe his own account ||.

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Lowitz's method of obtaining pure acetous acid.

"I have long been accustomed (says he) to prepare concentrated vinegar by congelation in the following manner: I freeze a whole barrel of vinegar as much as possible, then distil the remaining unfrozen vinegar in a water-bath; by which means I at first especially collect the spirituous ethereal part; the vinegar, which next comes over, I freeze again as much as possible, and afterwards purify it, by distilling it again with three or four pounds of charcoal powder. Thus I never fail to get a very pure, sweet-smelling, highly concentrated vinegar; the agreeable odour of which, however, may be

|| Crell's Journal, i. 242. Eng. Transl.

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still

(1) Count Muffin-Puschin having boiled a solution of carbonat of potash on purified phosphorus, obtained carbon. This he considered as an instance of the decomposition of carbonic acid, and as a confirmation of the experiments related in the text. See *Ann. de Chim.* xxv. 105.

(κ) At least near the surface of the earth. Lamanon, Mongez, and the other unfortunate philosophers who accompanied La Perouse in his last voyage, have rendered it not improbable that at great heights the quantity of this gas is much smaller. They could detect none in the atmosphere at the summit of the Peak of Teneriffe. See *Lamanon's Memoir at the end of La Perouse's Voyage.*

Acetous
Acid.

still improved by the addition of a proper quantity of the ethereal liquor collected at the beginning of the first distillation, but which must be previously dephlegmated by two or three rectifications.

"After the distillation in the water-bath was over, that no vinegar might be lost, I used to move the retort, with the charcoal powder which remained in it, to a sand-bath; and thus I obtained, by means of a strong fire, a few ounces more of a remarkably concentrated vinegar, which was of a yellow colour.

"Having collected about ten ounces of this concentrated vinegar, I exposed it last winter in the month of December to a cold equal to -22° ; in which situation it shot into crystals from every part. I let what remained fluid drop away from the crystals into a basin placed underneath, first in the cold air, and afterwards at the window within doors. There remained in the bottle snow-white finely foliated crystals, closely accumulated one upon the other, and which I at first took to be nothing but ice: on placing them upon the warm stove, they dissolved into a fluid which was perfectly as limpid as water, had an uncommonly strong, highly pungent, and almost suffocating acetous smell, and in the temperature of -37° immediately congealed into a solid white crystallized mass, resembling camphor.

"After I had observed that vinegar in this state is of such an extraordinary strength and purity as to be in its highest degree of perfection, I took all possible pains to find out a method of obtaining all the acetous acid in the state of glacial vinegar.

"To avoid circumlocution, I shall denote the strength of each sort of vinegar, which it was necessary for me to know in my experiments, by degrees, which I ascertain in the following manner: *viz.* to one drachm of vinegar I add, drop by drop, a clear solution of equal parts of carbonate of potash and water, till all at once a cloudiness or precipitation appears. Although, on the appearance of this sign, the acid is already super-saturated with the alkali, yet it seems to me to be a more accurate test for ascertaining its strength than the cessation of effervescence; for as the point of saturation approaches, the effervescence becomes so imperceptible, that it is almost impossible to determine with precision when it is really at an end. Now, every five drops of the alkaline solution, which I find it necessary to add to the vinegar till the precipitation takes place, I reckon as one degree. Thus, for example, if a determinate quantity of vinegar requires 25 drops for that effect, I denote its strength by five degrees. This is about the strength of good distilled vinegar.

"I call that vinegar which, in consequence of its concentration, is capable of crystallizing in a great degree of cold, *crystallizable vinegar*; the crystals of vinegar, separated after the crystallization is completed from the remaining fluid portion, I call *glacial vinegar*; and, lastly, to the fluid residuum I give the name of *mother-ley of vinegar*.

"From a great number of experiments, I have found that vinegar must have at least 24 degrees of concentration before it can be brought to crystallize by exposure to the most intense cold. Vinegar must be of the strength of 42 degrees at least, in order to become glacial vinegar; *viz.* in this state of concentration it has the property of crystallizing in a degree of cold not exceeding that in which water begins to freeze.

Acetous
Acid.

"I have found that charcoal, on being distilled with vinegar in a water-bath, possesses the singular and hitherto unknown property of imbibing a certain quantity of the acetous acid in a very concentrated state, and of retaining it so strongly, that the acid cannot be separated from it again but by the application of a considerably greater degree of heat than that of boiling water. Upon this circumstance is founded the new method which I have discovered of concentrating vinegar, so as to obtain all its acid in the purest state, *viz.* that of a glacial vinegar.

"Let a barrel of vinegar be concentrated by freezing in the manner above described, and let the concentrated vinegar thus obtained, free from all inflammable or spirituous parts, be put into two retorts: Add to each of them five pounds of good charcoal reduced to a fine powder, and subject them to distillation in a water-bath. When no more drops of vinegar come over, put the distilled liquor into two fresh retorts; and after adding five pounds of charcoal powder to each, proceed as before to the distillation in a water-bath. In the mean while, the two first retorts are to be placed in a sand-bath, that, by means of a brisk fire, the crystallizable vinegar, which is retained in the apparently dry charcoal powder, may be expelled from it. The heat must be strong enough to make the drops follow one another every two seconds; and when, in this degree of heat, 20 seconds intervene between each drop, the vinegar which has been collected must be removed; for what follows is hardly any thing else but mere water. In this manner about six ounces and a half of crystallizable vinegar, which is generally of the strength of between 36 and 40 degrees, may be collected from each retort. As soon as the distillation by the water-bath in the two retorts is over, the distilled liquor is to be poured back again into the first retorts upon the charcoal powder, which remains in them, and which has been already used; and from each of these retorts the remaining crystallizable vinegar (which generally amounts to as much as the first quantity) is to be abstracted by distillation in a sand-bath. These operations may be alternately repeated till all the acid of the vinegar which had been concentrated by freezing is converted into crystallizable vinegar; or until the distilled liquor, constantly becoming weaker and weaker at every repetition of the distillation, comes over at length in the state of mere water, which, with the above mentioned quantity of charcoal powder, generally happens at the fourth or fifth distillation. Now, in order to obtain the greatest part of the pure acid contained in the crystallizable vinegar in the form of glacial vinegar, it must be set to crystallize in a great degree of cold; and the mother-ley must be afterwards thoroughly drained from the glacial vinegar, by letting it drop from the crystals, first in the cold, and then in the room before the window. The mother-ley may be rendered further crystallizable by distilling it with a little charcoal powder; the weaker part, which comes over first, being put aside. But if a person wishes to keep the crystallizable vinegar for other purposes, and without separating any glacial vinegar from it, he must distil the whole of it again with charcoal powder in a sand-bath.

"I have found by accurate experiments, that, by means of this curious process, ten pounds of vinegar, concentrated by freezing to the 60th degree, may be made

Acetous
Acid.

made to yield 38 ounces of crystallizable vinegar, from which 20 ounces of glacial vinegar may be obtained.

“What constitutes the excellence of this method is, that the concentration and purification are effected by one and the same medium, viz. the charcoal powder; in consequence of which, both intentions are fulfilled at the same time.

“Last year, after much reflection, I was so happy as to find out another very effectual method of separating the acetous acid from the other substances combined with it, so as to obtain it at once in the state of a glacial vinegar of the greatest possible strength. The separating medium which I thought of is sulphat of potass supersaturated with sulphuric acid; a salt in which, conformably to my purpose, the sulphuric acid exists in a perfectly dry and dephlegmated state.

“By means of this salt a highly concentrated glacial vinegar may be obtained in the following manner:

“Let three parts of acetated soda, prepared with vinegar distilled over charcoal, and evaporated to perfect dryness, be melted in a strong heat; then pour it out, and rub it to a very fine powder. Mix this powder very accurately with eight parts of supersaturated sulphat of potass that has been previously well dried, and in like manner reduced to a fine powder; put the whole into a retort, and distil with a gentle heat, in such manner that, along with the drops, some vapours also may be perceived to come out of the neck of the retort; but by no means so that the receiver shall be filled with these vapours. Notwithstanding the moderate heat, the vinegar comes over very fast, and the quantity of glacial vinegar, of the strength of 54 degrees, which is thus obtained, amounts to nearly two parts.”

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Action of
acetous a-
cid on o-
ther bo-
dies.

Acetous acid is capable of oxidating iron, zinc, lead, nickel, tin, copper.

It does not act upon gold, silver, platinum, mercury, bismuth, cobalt, antimony, arsenic.

It combines with alkalies, alkaline earths, and alumina, and metallic oxides, and forms compounds known by the name of *acetites*.

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Its affini-
ties.

Its affinities are as follows:

Barytes,
Potass,
Soda,
Strontites?
Lime,
Magnesia,
Ammonia,
Oxide of zinc,
———— manganese,
———— iron,
———— lead,
———— tin,
———— cobalt,
———— copper,
———— nickel,
———— arsenic,
———— bismuth,
———— mercury,
———— antimony,
———— silver,
———— gold,
———— platinum,
Alumina*,
Jargonja †?

* Lavoisier.
† Vauquelin,
Ann. de
Chim. xxii.
208.Water,
Alcohol,Acetic
Acid.

SECT. XII. Of Acetic Acid.

If acetite of copper be distilled, an acid comes over of a more pungent smell than acetous acid, capable of crystallizing, and having a stronger affinity for other bodies than acetous acid. It is called *acetic acid*, and is supposed to contain a larger proportion of oxygen than acetous acid. This additional dose it is supposed to receive from the oxide of copper, which during the process is reduced to the metallic state. It can hardly be doubted that the glacial vinegar of Lowitz, described in the preceding section, is really acetic acid, though it would perhaps be difficult to explain its formation. Its affinities are the same with those of the acetous acid.

SECT. XIII. Of Oxalic Acid.

SUGAR, a well-known substance extracted from the sugar-cane, appears to have been used in the East at a very early period; but it made its way westward very slowly. As a medicine, it is mentioned by Dioscorides; but it was not in common use in Europe till after the 14th century.

It has been proved that sugar is composed of oxygen, carbon, and hydrogen. Lavoisier concluded, from a long series of delicate experiments, that it consists of 8 parts⁴⁶⁶ of hydrogen, 64 of oxygen, and 28 of carbon.

From sugar, by a particular process, an acid has been⁴⁶⁷ obtained called *oxalic acid*, because it exists ready formed, as Scheele has proved, in the *oxalis acetosella*, or wood sorrel. At first, however, it was called the *acid of sugar*, or the *saccharine acid*.

As the earliest and best account of the oxalic acid was published by Bergman, he was for a long time reckoned the discoverer of it; but Mr Ehrhart, one of Scheele's intimate friends, informs us, that the world is indebted for its knowledge of this acid to that illustrious chemist*, and Hermstadt and Westrum assign the discovery to the same author†. The assertions of these gentlemen, who had the best opportunity of obtaining accurate information, are certainly sufficient to establish the fact, that Scheele was the real discoverer of oxalic acid.⁴⁶⁸

Bergman gives us the following process for obtaining this acid. “Put one ounce of white sugar powdered into a tubulated retort, with three ounces of strong nitric acid, the specific gravity of which is to that of water as 1,567. When the solution is over, during which many fumes of the nitrous acid escape, let a receiver be fitted, and the liquor made to boil, by which abundance of nitrous gas is expelled. When the liquor in the retort acquires a reddish brown colour, add three ounces more of nitric acid, and continue the boiling till the fumes cease, and the colour of the liquor vanishes. Then let the contents of the retort be emptied into a wide vessel; and upon cooling, a crystallization will take place of slender, quadrilateral prisms, which are often affixed to each other at an angle of 45°. These crystals, collected and dried on blotting paper, will be found to weigh 1½ dr. 19 gr. By boiling the remaining lixivium with two ounces of nitric acid in the retort, till the red fumes almost disappear, and by repeating the crystallization as before, ¼ dr. 13 gr. of solid acid will be obtained. If the process be repeated

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once

Oxalic
Acid.

once more upon the residuum, which has now a glutinous consistence, with the successive additions of small quantities of nitric acid, amounting in all to two ounces, a saline brown deliquescent mass will be formed, weighing half a dram, of which about a half will be lost by a farther purification. The crystals obtained thus at different times may be purified by solution and crystallization, and by digesting the last lixivium with some nitric acid, and evaporation with the heat of the sun."

By the same process Bergman obtained it from gum arabic, alcohol, and honey: Scheele, Hermstadt, Westrum, Hoffman, &c. from a great variety of other vegetable productions; and Berthollet from a great number of animal substances.

It is of great consequence not to use too much nitric acid, otherwise the quantity of oxalic acid will be diminished; and if a very great quantity of nitric acid be used, no oxalic acid will be obtained at all*. On the contrary, if too small a quantity of nitric acid be used, the acid obtained will not be the oxalic, but the tartarous†. We think we have observed, that a considerably larger proportion of oxalic acid may be obtained by pouring nitric acid on sugar, and allowing these substances to act upon each other while cold. When the process is conducted in that manner, hardly any thing separates but nitrous gas.

* Bergman.
† Hermstadt.469
Its properties.

Oxalic acid is capable of crystallization, or rather it is generally obtained in that state. Its crystals are quadrilateral prisms, the ends of which often terminate in ridges‡.

‡ Bergman,
i. 255.

They are soluble in their own weight of boiling water: water at the temperature of 65,7° dissolves half its weight of them. The specific gravity of the solution is 1,0593 ||. One hundred parts of boiling alcohol dissolve 56 parts of these crystals; but at a mean temperature only 40 parts §. They are not easily soluble in ether. Fixed and volatile oils dissolve them, and they may be again obtained by gentle evaporation. Too violent a heat would sublime the acid itself.

|| Ibid.

§ Ibid.

Oxalic acid has a very acrid taste when it is concentrated, but a very agreeable acid taste when sufficiently diluted with water ¶.

¶ Ibid.

It changes all vegetable blues except indigo to a red. One grain of crystallized acid, dissolved in 1920 grains of water, reddens the blue paper with which sugar loaves are wrapt: one grain of it, dissolved in 3600 grains of water, reddens paper stained with turnsole*. According to Morveau, one part of the crystallized acid is sufficient to communicate a sensible acidity to 2633 parts of water †.

* Ibid.

† Encyclo-
Method.
art. Acide
Saccharin.

Its fixity is such, that none of it is sublimed when water containing it in solution is raised to the boiling temperature.

When this crystallized acid is exposed to heat in an open vessel, there arises a smoke from it, which affects disagreeably the nose and lungs. The residuum is a powder of a much whiter colour than the acid had been. By this process it loses $\frac{1}{10}$ ths of its weight; but soon recovers them again on exposure to the air. When distilled, it first loses its water of crystallization, then liquifies and becomes brown; a little phlegm passes over, a white saline crust sublimes, some part of which passes into the receiver; but the greatest part of the acid is destroyed, leaving in the retort a mass $\frac{7}{10}$ th of the whole,

which has an empyreumatic smell, blackens sulphuric acid, renders nitric acid yellow, and dissolves in muriatic acid without alteration. That part of the acid which sublimes is unaltered. When this acid is distilled a second time, it gives out a white smoke, which, condensing in the receiver, produces a colourless uncrystallizable acid, and a dark coloured matter remains behind*. * Bergman. During all this distillation a vast quantity of elastic vapour makes its escape. From 279 grains of oxalic acid, Bergman obtained 109 cubic inches of gas, half of which was carbonic acid and half hydrogen. Fontana from an ounce of it obtained 430 cubic inches of gas, one-third of which was carbonic acid, the rest hydrogen. From these facts, it is evident that oxalic acid is composed of oxygen, hydrogen, and carbon; but the proportions are still unknown.

When nitric acid is frequently distilled off oxalic acid, acetic acid is produced †. The sulphuric acid, when concentrated, seems to produce the same effect. Muriatic and acetic acids dissolve oxalic acid, but without altering it ‡.

Oxalic acid is capable of oxidating lead, copper, iron, tin, bismuth, nickel, cobalt, zinc, manganese.

It does not act upon gold, silver, platinum, mercury, arsenic §.

Oxalic acid combines with alkalis, alkaline earths, and alumina, and metallic oxides, and forms salts known by the name of *oxalats*.

Its affinities, according to Bergman, are as follows: † Bergman.
470
Its action
on other
bodies.

Lime,
Barytes,
Strontites §,
Magnesia,
Potash,
Soda,
Ammonia,
Alumina,
Jargonia || ?
Metallic oxides as in sulphuric acid,
Water,
Alcohol.

† Bergman.
470
Its action
on other
bodies.§ Dr Hope,
Transf. Edin.
iv.|| Vauquelin,
Ann. de
Chim. xxii.
208.

SECT. XIV. Of Tartarous Acid.

TARTAR, or *cream of tartar* as it is commonly called when pure, has occupied the attention of chemists for several centuries. Duhamel and Grosse, and after them Margraf and Rouelle the Younger, proved that it was composed of an acid united to potash: but Scheele was the first who obtained this acid in a separate state. He communicated his process for obtaining it to Retzius, who published it in the Stockholm Transactions for 1770. It consisted in boiling tartar with lime, and in decomposing the tartrate of lime thus formed by means of sulphuric acid.

This acid, by a gentle evaporation, yields crystals so irregular in their figure, that every chemist who has treated of this subject has given a different description of them. According to Bergman, they generally consist of divaricating lamellæ*; according to Van Packeren, they assume oftenest the form of long pointed prisms †; Spielman and Corvinus ‡ obtained them in groups, some of them lance-shaped, others needle-form, others pyramidal. Morveau obtained them needle-form §. They do not experience any change in the air; heat 323.

472
Discovery
of tartarous
acid.† Bergman,
iii. 308.‡ De Sale
Essent. acid
Tartari.§ Encyclo-
Method.
Chim. i.

Citric Acid.

Part II.

Citric Acid.

* Bergman, *ibid* and ii. 465
† Spielman and Corvinnus, *ibid.*
‡ Hermsstadt and Westrum.

heat decomposes them. In the open fire they burn without leaving any other residuum than a coal, which generally contains a little lime *. In close vessels, the product is carbonic acid and hydrogen gas †. If the proper quantity of nitric acid be distilled off the crystals, they are converted into oxalic acid, and the nitric acid, as usual, passes into the nitrous acid ‡. Hence it is evident that tartarous acid also, like the four former, is composed of oxygen, hydrogen, and carbon; but the proportions are equally unascertained.

§ Bergman, i. 250.

This acid, when in crystals, dissolves readily in water. Bergman obtained a solution, the specific gravity of which was 1,230 §. Morveau observed, however, that crystals formed spontaneously in a solution, the specific gravity of which was 1,084.

474 Its action on other bodies.

It has a very sharp acid taste, and reddens vegetable blues.

Tartarous acid does not oxidate gold, silver, platinum, lead, bismuth, nor tin, and hardly antimony and nickel.

It combines with alkalis, alkaline earths, and alumina, and metallic oxides, and forms salts known by the name of *tartrites*.

475 Its affinities.

The order of its affinities is the same as that given for oxalic acid; except that, according to Lavoisier, the oxide of silver comes before that of mercury.

SECT. XV. Of Citric Acid.

476 Method of obtaining citric acid.

CHEMISTS have always considered the juice of oranges and lemons as a peculiar acid. This juice contains a quantity of mucilage and water, which render the acid impure, and subject to spontaneous decomposition. Mr Georgius took the following method to separate the mucilage. He filled a bottle entirely with lemon-juice, corked it, and placed it in a cellar: in four years the liquid was become as limpid as water, a quantity of mucilage had fallen to the bottom in the form of flakes, and a thick crust had formed under the cork. He exposed this acid to a cold of 23°, which froze a great part of the water, and left behind a strong and pretty pure acid ||. It was Scheele, however, that first pointed out a method of obtaining this acid perfectly pure. He saturated lemon-juice with lime, edulcorated the precipitate, which consisted of citric acid and lime, separated the lime from it by diluted sulphuric acid, cleared it from the sulphat of lime by repeated filtrations and evaporation; then evaporated it to the consistence of a syrup, and set it by in a cool place: a quantity of crystals formed, which were pure citric acid ¶. It exists ready formed also in the juices of the following berries: *Vaccinium occicoccus*, *vaccinium vitis idæa*, *prunus padus*, *solanum dulcamara*, *rosa canina* *, *cherries* †.

|| Stockholm Transf. 1774.

¶ Scheele's Essays.

* Scheele, *Crell's Annals*, 1788.
† Westrum.

Scheele advises the use of an excess of sulphuric acid, in order to ensure the separation of all the lime; but according to Dizé, this excess is necessary for another purpose ‡. A quantity of mucilage still adheres to the citric acid in its combination with lime, and sulphuric acid is necessary to decompose this mucilage, which, as Fourcroy and Vauquelin have proved, it is capable of doing. His proof of the presence of mucilage is, that when the solution of citric acid in water, which he had obtained, was sufficiently concentrated by evaporation, it assumed a brown colour, and even became black to-

wards the end of the evaporation. The crystals also were black. By repeated solutions and evaporations, this black matter was separated, and found to be carbon. Hence he concluded that mucilage had been present; for mucilage is composed of carbon, hydrogen, and oxygen; sulphuric acid causes the hydrogen and oxygen to combine and form water, and the carbon remains behind. It is not certain, however, as Mr Nicholson remarks very justly *, that the sulphuric acid may not act upon the citric acid itself, and that the carbon may not proceed from the decomposition of it; at least the experiments of Mr Dizé are insufficient to prove the contrary. In that case the smaller the excess of sulphuric acid used the better.

* Nicholson, *ibid.*

The crystals of citric acid are rhomboidal prisms, the sides of which are inclined to each other in angles of about 120 and 60 degrees, terminated at each end by four trapezoidal faces, which include the solid angles †. They are not altered by exposure to the air.

477 Its properties.

An ounce of distilled water, at the temperature of the atmosphere, dissolves one ounce and two drams of crystallized citric acid; and during the solution the temperature is lowered 29,75°. Boiling water dissolves twice its weight of this acid ‡.

† Dizé, *ibid.*

Citric acid has a very acid taste; it turns vegetable blues to a red.

‡ *Id. ibid.*

It is capable of oxidating iron, zinc, tin. It does not act upon gold, silver, platinum, mercury, bismuth, antimony, arsenic.

478 Its action on other bodies.

It combines with alkalis, alkaline earths, and alumina, and metallic oxides, and forms salts known by the name of *citrats*.

Fire decomposes this acid, converting it into an acidulous phlegm, carbonic acid gas, and carbonated hydrogen gas. Its solution in water is also gradually decomposed, if access of air be permitted. It is evident, therefore, that this acid is also composed of oxygen, hydrogen, and carbon.

Scheele said that he could not convert it into oxalic acid by means of nitric acid, as he had done several other acids; but Westrum affirms, that this conversion may be effected; and thinks that Scheele had probably failed from having used too large a quantity of nitric acid, by which he had proceeded beyond the conversion into oxalic acid, and had changed the citric acid into vinegar; and in support of his opinion, he quotes his own experiments: from which it appeared that, by treating sixty grains of citron acid with different quantities of nitric acid, his products were very different. Thus with 200 grains of nitric acid he got 30 grains of oxalic acid; with 300 grains of nitric acid he obtained only 15 grains of the oxalic acid; and with 600 grains of nitric acid no vestige appeared of the oxalic acid. On distilling the products of these experiments, especially of the last, he obtained vinegar mixed with nitric acid.

The affinities of this acid are as follows §:

- Lime (L),
- Barytes,
- Strontites ||,
- Magnesia,
- Potafs,

479 Its affinities. § See Bergman and Lavoisier. || Dr Hope, *Transf. Edin.*

Soda, *iv.*

(L) Mr De Bressy places barytes before lime.

Malic
Acid.

* *Lavoisier.*

† *Id.*

‡ *Id.*
§ *Vauquelin,*
Ann. de
Chim. xxii.
208.

Soda,
Ammonia,
Oxide of zinc,
----- manganese *,
----- iron,
----- lead,
----- cobalt,
----- copper,
----- arsenic,
----- mercury,
----- antimony †,
----- silver,
----- gold,
----- platinum,

Alumina ‡,
Jargonia § ?
Water,
Alcohol.

SECT. XVI. Of Malic Acid.

⁴⁸⁰ Discovery of malic acid. SCHEELLE discovered a peculiar acid in the juices of several fruits, which, because it is found most abundant-ly in apples, has been called *malic acid*.

⁴⁸¹ Method of obtaining it. He obtained it by the following process: Saturate the juice of apples with potash, and add to the solution acetite of lead till no more precipitation ensues. Wash the precipitate carefully with a sufficient quantity of water; then pour upon it diluted sulphuric acid till the mixture has a perfectly acid taste, without any of that sweetness which is perceptible as long as any lead remains dissolved in it; then separate the sulphat of lead, which has precipitated, by filtration, and there remains behind pure malic acid ||.

|| *Swedish*
Trans. and
Crell's An-
nals for
1785.
¶ *Ibid.*

This acid is contained in the berries of the *barberis vulgaris*, the *sambucus nigra*, the *prunus spinosa*, the *forbus aucuparia*, and the *prunus domestica* ¶.

If nitric acid be distilled with an equal quantity of sugar, till the mixture assumes a brown colour (which is a sign that all the nitric acid has been abstracted from it), this substance will be found of an acid taste; and after all the oxalic acid which may have been formed is separated by lime-water, there remains another acid, which may be obtained by the following process: Saturate it with lime, and filter the solution; then pour upon it a quantity of alcohol, and a coagulation takes place. This coagulum is the acid combined with lime. Separate it by filtration, and edulcorate it with fresh alcohol; then dissolve it in distilled water, and pour in acetite of lead till no more precipitation ensues. The precipitate is the acid combined with lead, from which it may be separated by diluted sulphuric acid. It possesses all the properties of malic acid *. This acid, therefore, may be obtained from sugar; and it may be converted into oxalic acid, by distilling off it the pro-
per quantity of nitric acid †.

* *Ibid.*

† *Hermstadt,*
Phys. Chem.

This acid bears a strong resemblance to the citric, but differs from it in the following particulars:

⁴⁸² Its proper-
ties.

1. The citric acid shoots into fine crystals, but this acid does not crystallize.

2. The salt formed from the citric acid with lime is almost insoluble in boiling water; whereas the salt made with malic acid and the same basis is readily soluble by boiling water.

3. Malic acid precipitates mercury, lead, and silver, from the nitrous acid, and also the solution of gold when

diluted with water; whereas citric acid does not alter any of these solutions.

Lactic
Acid.

3. Malic acid seems to have a less affinity than citric acid for lime; for when a solution of lime in the former acid is boiled one minute with a salt formed from volatile alkali and citric acid, a decomposition takes place, and the latter acid combines with the lime and is precipitated.

The malic acid combines with alkalis, alkaline earths, alumina, and metallic oxides, and forms salts known by the name of *malats*. ⁴⁸³ Its combina-
tions.

Its affinities have not yet been ascertained.

SECT. XVII. Of Lactic Acid.

If milk be kept for some time it becomes sour. The acid which then appears in it was first examined by Scheele, and found by him to have peculiar properties. It is called *lactic acid*. In the whey of milk this acid is mixed with a little curd, some phosphat of lime, sugar of milk, and mucilage. All these must be separated before the acid can be examined. Scheele accomplished this by the following process:

Evaporate a quantity of four whey to an eighth part, and then filtrate it: this separates the cheesy part. Sa-
turate the liquid with lime-water, and the phosphat of lime precipitates. Filtrate again, and dilute the liquid with three times its own bulk of water; then let fall in-
to it oxalic acid, drop by drop, to precipitate the lime which it has dissolved from the lime-water: then add a very small quantity of lime-water, to see whether too much oxalic acid has been added. If there has, oxalat of lime immediately precipitates. Evaporate the solu-
tion to the consistence of honey, pour in a sufficient quantity of alcohol, and filtrate again; the acid passes through dissolved in the alcohol, but the sugar of milk and every other substance remains behind. Add to the solution a small quantity of water, and distil with a small heat, the alcohol passes over, and leaves behind the lactic acid dissolved in water *.

This acid is incapable of crystallizing: when evaporated to dryness, it deliquesces again in the air †.

When distilled, water comes over first, then a weak acid resembling the tartarous, then an empyreumatic oil
mixed with more of the same acid, and lastly carbonic acid and hydrogen gas—there remains behind a small quantity of coal ‡.

The combinations which this acid forms with alkalis, earths, and metallic oxides, are called *lactats*. Its affinities, according to Bergman, are as follows: ⁴⁸⁷ And affini-
ties.

Barytes,
Potash,
Soda,
Ammonia,
Lime,
Magnesia,
Alumina,
Jargonia § ?
Metallic oxides as in *sulphuric acid*,
Water,
Alcohol.

§ *Vauquelin,*
Ann. de
Chim. xxii.
208.

SECT. XVIII. Of Saccholactic Acid.

If a quantity of fresh whey of milk be filtrated, and then evaporated by a gentle fire till it is of the consist-
ence of honey, and afterwards allowed to cool, a solid
milk.
sugar
mats

Saccholactic Acid.

mass is obtained. If this be dissolved in water, clarified with the white of eggs, filtrated, and evaporated to the consistence of a syrup, it deposits on cooling a number of brilliant, white, cubic crystals, which have a sweet taste, and for that reason have been called *sugar of milk*. Fabricius Bartholet, an Italian, was the first European who mentioned this sugar. He described it in his *Encyclopædia Hermetico dogmatica*, published at Boulognia in 1619; but it seems to have been known in India long before that period.

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Method of obtaining saccholactic acid.

After Mr Scheele had obtained oxalic acid from fugar, he wished to examine whether the sugar of milk would furnish the same product. Upon four ounces of pure sugar of milk, finely powdered, he poured 12 ounces of diluted nitric acid, and put the mixture in a large glass retort, which he placed in a sand-bath. A violent effervescence ensuing, he was obliged to remove the retort from the sand-bath till the commotion ceased. He then continued the distillation till the mixture became yellow. As no crystals appeared in the liquor remaining in the retort, after standing two days he repeated the distillation as before, with the addition of eight ounces of nitric acid, and continued the operation till the yellow colour, which had disappeared on addition of the nitrous acid, returned. The liquor in the retort contained a white powder, and when cold was observed to be thick. Eight ounces of water were added to dilute this liquor, which was then filtrated, by which the white powder was separated; which beingedulcorated and dried, weighed $7\frac{1}{2}$ dr. The filtrated solution was evaporated to the consistence of a syrup, and again subjected to distillation, with four ounces of nitric acid as before; after which, the liquor, when cold, was observed to contain many small, oblong, four crystals, together with some white powder. This powder being separated, the liquor was again distilled with more nitric acid as before; by which means the liquor was rendered capable of yielding crystals again; and by one distillation more, with more nitrous acid, the whole of the liquor was converted into crystals. These crystals, added together, weighed five drams; and were found, upon trial, to have the properties of the oxalic acid.

Mr Scheele next examined the properties of the white powder, and found it to be an acid of a peculiar nature; he therefore called it the *acid of sugar of milk*. It is now called the *saccholactic acid*.

490
Its properties.
* *Phys. Chem.*
† *Encyc. Method. i.*
290.
‡ *Scheele.*
§ *Id.*
|| *Morveau, ibid.*

According to Scheele, it is soluble in 60 parts of its weight of boiling water; but Messrs Hermtadt* and Morveau† found, that boiling water only dissolved $\frac{1}{10}$ th part: it deposited about $\frac{1}{4}$ th part on cooling in the form of crystals‡.

The solution has an acid taste, and reddens the infusion of turnsole§. Its specific gravity, at the temperature of 53.7° , is 1,0015 ||.

When distilled, it melts very readily, becomes black, and frothes; a brown salt sublimes into the neck of the retort, which has the odour of a mixture of amber and benzoin, having an acid taste, easily soluble in alcohol,

with greater difficulty in water, and burning in the fire with a flame. There passes into the receiver a brown liquid, having some of this salt dissolved in it: There remains behind a coal*, which Hermtadt found to contain a small quantity of lime. Concentrated sulphuric acid distilled on this salt becomes black, frothes, and decomposes it †.

Mr Hermtadt of Berlin had made similar experiments on sugar of milk at the same time with Scheele, and with similar results; but he concluded that the white powder which he obtained was nothing else than oxalat of lime with excess of acid, as indeed Scheele himself did at first. After he became acquainted with Scheele's conclusions, he published a paper in defence of his own opinion; but his proofs are very far from establishing it, or even rendering its truth probable. He acknowledges himself, that he has not been able to decompose this supposed salt: he allows that it possesses properties distinct from the oxalic acid; but he ascribes this difference to the lime which it contains; yet all the lime which he could discover in 240 grains of this salt was only 20 grains; and if the alkali which he employed was a carbonat (as it probably was), these 20 must be reduced to 11. Now Morveau has shewn, that oxalic acid, containing the same quantity of lime, exhibits very different properties. Besides, this acid, whatever it is when united with lime, is separated by the oxalic, and must therefore be different from it, as it would be absurd to suppose that an acid could displace itself ‡. The saccholactic acid must therefore be considered as a distinct acid, as it possesses peculiar properties.

Its compounds with alkalies, earths, and metallic oxides, are denominated *saccholats*.

Its affinities, according to Bergman, are as follows:

Lime,
Barytes,
Magnesia,
Potash,
Soda,
Ammonia,
Alumina,
Jargonias §?
Metallic oxides as in *sulphuric acid*,
Water,
Alcohol.

† *Morveau, Encyc. Method. i.*
p. 291.
492
Its compounds and affinities.§ *Vauquelin, Ann. de Chim. xxii.*
208.

SECT. XIX. Of Gallic Acid.

THERE is an excrescence, known by the name of *nut-gall*, which grows on some species of oaks. This substance contains a peculiar acid, called from that circumstance *gallic acid*, the properties of which were first examined with attention by the commissioners of the academy of Dijon; and the result of their experiments was published in 1777, in the third volume of their *Elements of Chemistry*. In these experiments, however, they employed the infusion of galls, in which the acid is combined with the tanning principle (M). It was reserved for Scheele to obtain it in a state of purity.

He

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Nat-galls.

(M) A substance lately discovered by French chemists, which exists also in oak-bark, and every other body which may be substituted for that bark in the operation of tanning. It resembles the resins in many properties; but its distinguishing property is that of forming with glue a compound insoluble in water. When a little of the decoction of glue is dropped into an infusion of nut-galls, a white curdy precipitate is instantly seen: This is the tanning principle combined with glue. The name *tanning principle* has been applied to it, because *tanning* consists in combining this principle with *skins*, by which they are converted into leather.

Gallic Acid.
494
Discovery of gallic acid.

He observed, in an infusion of galls made with cold water, a sediment, which proved on examination to have a crystalline form and an acid taste. By letting an infusion of galls remain a long time exposed to the air, and removing now and then the mouldy skin which formed on its surface, a large quantity of this sediment was obtained; which beingedulcorated with cold water, redissolved in hot water, filtrated, and evaporated very slowly, yielded an acid salt in crystals as fine as sand*.

* Stockholm Transf. 1786.

495
Method of obtaining it.

There is a shorter method of obtaining this acid in a still purer state than Scheele obtained it. Pour sulphuric ether on a quantity of powdered galls, and allow it to remain a few hours; by which time it becomes coloured. Put this tincture into a retort, and distil off the ether with a small heat. The residuum possesses the colour and brittleness of a resin, and has all the characters of Rouelle's residuous-extract; it does not attract moisture from the atmosphere. Dissolve it in its own weight of water, and add sulphuric acid, drop by drop, till the liquor has become of a manifestly acid taste. It causes a white precipitate, which becomes coloured, and is immediately redissolved. At the end of some hours a resinous matter will have precipitated. Decant off the fluid, dilute it with half its weight of water, filtrate and evaporate it to $\frac{3}{4}$ ths in a moderate heat; add pure barytes till the liquor is no longer capable of decomposing muriat of barytes; then filtrate it again; and on evaporation in a moderate heat small white prismatic crystals of gallic acid are formed on the sides of the vessel †.

† Mr F. J. Dizé Jour. de Phys. Dec. 1791. † Ann. de Chim. xvii. 3.

It appears from the experiments of Deyeux, that the substance extracted from nut-galls by ether does not differ much from the extract by water †. Probably, then, the only reason for employing ether is the small heat necessary for evaporating it.

§ Ibid.

496
Proust's method.

There is still another method of obtaining this acid. Distil nut-galls in a strong heat, a white substance sublimes, which crystallizes in the form of needles: This is gallic acid. If the crystals are impure, they may be purified by a second sublimation: but the heat must not be too violent, otherwise the crystals will melt into a brown mass †. This process was discovered by Scheele.

But the most elegant method of obtaining gallic acid is that of Mr Proust. When a solution of muriat of tin is poured into an infusion of nut-galls, a copious yellow precipitate is instantly formed, consisting of the tanning principle, combined with the oxide of tin. After diluting the liquid with a sufficient quantity of water to separate any portion of this precipitate which the acids might hold in solution, the precipitate is to be separated by filtration. The liquid contains gallic acid, muriatic acid, and muriat of tin. To separate the tin, a quantity of sulphurated hydrogen gas is to be mixed with the liquid. Sulphuret of oxide of tin is precipitated under the form of a brown powder. The liquid is then to be exposed for some days to the light, covered with paper, till the superfluous sulphurated hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and put by to cool. Crystals of gallic acid are deposited. These are to be separated by filtration, and washed with a little cold water. The evaporation of the rest of the liquid is to be repeated till all the gallic acid is obtained from it †.

|| Ibid. xv. 225.

The gallic acid thus obtained has a very acid taste, and reddens vegetable colours. It is soluble in $1\frac{1}{2}$ parts of boiling water, and in 12 parts of water at the temperature of the atmosphere. Alcohol dissolves one-fourth of its weight of this acid at the temperature of the atmosphere. When boiling hot it dissolves a quantity equal to its own weight.

Gallic Acid.
497
Its properties.

When placed upon burning coals, gallic acid takes fire, and at the same time diffuses a very strong odour, which has something aromatic in it. When strongly heated, it melts, boils, becomes black, is dissipated, and leaves a quantity of charcoal behind it. When distilled, a quantity of oxygen gas is disengaged, an acid liquor is found in the receiver, with some gallic acid not decomposed, and there remains in the retort a quantity of carbon. If what has passed into the receiver be again distilled, more oxygen gas is obtained, some gallic acid still sublimes, and a quantity of carbon remains in the retort. By repeated distillations the whole of the acid may be decomposed. This decomposition may be more easily accomplished by distilling repeatedly a solution of gallic acid in water. The products are oxygen gas, charcoal, and an acid liquor.

From these experiments, Mr Deyeux, who performed them, has concluded, that gallic acid is composed of oxygen, and a much larger proportion of carbon than enters into the composition of carbonic acid. But this conclusion is not warranted by the analysis; for Mr Deyeux did not find that the quantity of oxygen gas and carbon obtained was equal to that of the gallic acid decomposed: and in the acid liquor which came over, there evidently existed a quantity of water, which doubtless was formed during the distillation. Scheele, by treating gallic acid with nitric acid in the usual manner, converted it into oxalic acid. Now it is certain that oxalic acid contains hydrogen as well as carbon. It cannot be doubted, then, that gallic acid is composed of oxygen, hydrogen, and carbon, in proportions not yet ascertained. But Mr Deyeux has proved, that the quantity of carbon is very great, compared with that of the hydrogen.

Gallic acid combines with alkalies, earths, and metallic oxides, and forms compounds known by the name of *gallats*.

Its affinities have not yet been determined; but oxide of iron seems to have a stronger affinity for it than for any other substance; for gallic acid is capable of taking it from every other acid. In consequence of this property, the infusion of galls is employed to detect the presence of iron in any liquid. As soon as it is poured in, if iron be present, a black or purple colour is produced.

SECT. XX. Of Benzoic acid.

BENZOIN or *benjamin* (as it is sometimes called) is a kind of resin brought from the East Indies; obtained, according to Dr Dryander, from the styrax benzoe, a tree which grows in the island of Sumatra. This substance consists partly of a peculiar acid, described as long ago as 1608 by Blaise de Vigenere, in his Treatise on Fire and Salt, under the name of *flowers of benzoïn*, because it was obtained by sublimation. This acid, which is now called *the benzoic acid*, may be sublimed from benzoïn by heat; or it may be obtained by Scheele's

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Succinic Acid. Scheele's process, which has been described in the article CHEMISTRY, *Encycl.*

⁵⁰⁰ Properties of benzoic acid. Benzoic acid has little or none of the peculiar odour which distinguishes benzoin. Its taste is not acid, but sweetish, and very pungent *. It hardly affects the infusion of violets; but it reddens that of turnsole, especially if that infusion be hot †. Heat volatilizes this acid, and makes it give out a strong odour, which excites coughing. When exposed to the heat of the blow-pipe in a silver spoon, it melts, becomes as fluid as water, and evaporates without taking fire. It only burns when in contact with flame, and then it leaves no residuum behind. When thrown upon burning coals, it rises in a white smoke. When allowed to cool after being melted, it hardens, and a radiated crust forms on its surface ‡.

It suffers no other alteration in the air than losing the little of the odour of benzoin which remained to it §.

¶ Cold water dissolves no sensible quantity of it; but it is soluble enough in hot water: 480 grains of boiling water dissolve 20 grains of it; 19 of these are deposited, when the water cools, in long, slender, flat, feather-like crystals ||.

Concentrated sulphuric acid dissolves it without heat or any other change except becoming somewhat brown: when water is poured into the solution, the benzoic acid separates and coagulates on the surface without any alteration ¶. Nitric acid presents precisely the same phenomena, and also the sulphurous and nitrous acids. Neither the muriatic, the oxy-muriatic, nor the phosphoric acids dissolve it. The acetous, formic, and sebacic acids, when hot, dissolve it precisely as water does; but it crystallizes again when these acids cool *.

Alcohol dissolves it copiously, and lets it fall on the addition of water †.

⁵⁰¹ Little is known respecting its base. It combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *benzoates*.

Its affinities, from the experiments of Trommsdorf, appear to be as follows:

- White oxide of arsenic,
- Potash,
- Soda,
- Ammonia,
- Barytes,
- Lime,
- Magnesia,
- Alumina,
- Jargonia ‡?
- Water,
- Alcohol.

SECT. XXI. *Of Succinic Acid.*

⁵⁰² AMBER is a well-known brown, transparent, inflammable body, pretty hard, and susceptible of polish, found at some depth in the earth, and on the sea-coast of several countries. It was in high estimation among the ancients both as an ornament and a medicine.—When this substance is distilled, a volatile salt is obtained, which is mentioned by Agricola under the name of *salt of amber*; but its nature was long unknown. Boyle was the first who discovered that it was an acid §. From *succinum*, the Latin name of amber, this acid has received the appellation of *succinic acid*.

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§ Boyle *abridged by Shaw*, iii. 369.

† *Vauquelin, Ann. de Chim.* xxii. 208.

It is obtained by the following process: Fill a retort half way with powdered amber, and cover the powder with a quantity of dry sand; lute on a receiver, and distil in a sand-bath without employing too much heat. There passes over first an insipid phlegm; then a weak acid, which, according to Scheele, is the acetous*; then the succinic acid attaches itself to the neck of the retort; and if the distillation be continued, there comes over at last a thick brown oil, which has an acid taste.

The succinic acid is at first mixed with a quantity of oil. Perhaps the best method of purifying it is that recommended by Pott, to dissolve it in hot water, and to put upon the filter a little cotton, previously moistened with oil of amber; this substance retains most of the oil, and allows the solution to pass clear. The acid is then to be crystallized by a gentle evaporation. And this process is to be repeated till the acid be quite pure. The crystals are white, shining, and of a foliated triangular prismatic form: they have an acid taste, but are not corrosive: they redden tincture of turnsole, but have little effect on that of violets.

They sublime when exposed to a considerable heat, but not at the heat of a water-bath. In a sand-bath they melt, and then sublime and condense in the upper part of the vessel; but the coal which remains shews that they are partly decomposed †.

One part of this acid dissolves in 96 parts of water at the temperature of 50°, according to Spielman ‡, in 24 parts at the temperature of 52°, and in 2 parts of water at the temperature of 212°, according to Stockar de Neuforn §; but the greatest part crystallizes as the water cools. According to Roux, however, it still retains more of the acid than cold water is capable of dissolving ||.

240 grains of boiling alcohol dissolve 177 of this acid; but crystals again shoot as the solution cools ¶.

The combinations of this acid are called *succinats*. Its component parts are still unknown.

Its affinities, according to Morveau, are as follows:

- Barytes,
- Lime,
- Potash,
- Soda,
- Ammonia,
- Magnesia,
- Alumina,
- Jargonia *?
- Metallic oxides as in *sulphuric acid*,
- Water,
- Alcohol.

SECT. XXII. *Of Camphoric Acid.*

CAMPHOR is a well-known white crystalline substance, of a strong taste and smell, obtained from a species of laurel in the East Indies; and Mr Proust has shewn that several volatile oils contain a considerable quantity of it †. It is so volatile, that it cannot be melted in open vessels, and so inflammable that it burns even on the surface of water.

When camphor is set on fire in contact with oxygen gas, it burns with a very brilliant flame; much caloric is disengaged, water is formed, the inner surface of the vessel is covered with a black matter, which is undoubtedly carbon, and a quantity of carbonic acid gas is also produced ‡. Hence it follows, that it is composed of hydrogen and carbon, at least principally.

T t

Camphoric Acid.

Method of obtaining succinic acid. *Bergman's Notes on Scheffer.*

its properties.

† Pott.

‡ *Inst. Chem.* § xii.

§ *De Succin.*

|| *Morveau, ibid.* p. 72.

¶ *Wenzel.*

Combinations and affinities.

* *Vauquelin, Ann. de Chim.* xxii. 208.

506 Camphor.

† *Ann. de Chim.* iv. 179.

‡ *La Grange, ibid.* xxiii.

If 53.

Camphoric Acid.

If one part of camphor and six parts of pulverified clay be mixed together, by means of alcohol, in a mortar, the mixture made up into balls, and when dry put into a retort, and distilled by a moderate heat—a quantity of oil comes over, and there remains in the retort a black substance, which consists of the clay intimately mixed with a quantity of carbon. If the fire be not cautiously managed, a quantity of camphor also sublimes. By this process camphor is decomposed, and separated into oil and carbon.

122,248 parts of camphor
produced 45,856 parts of oil
and 30,571 of carbon.

Total 76,427
Loss 45,821

Carbonated hydrogen gas and carbonic acid were also formed*.

* *Ann. de Chim.* xxii. The oil obtained has the following properties:

† 53. It has a sharp caustic taste, and leaves upon the tongue a sense of coldness. It has an aromatic odour, approaching to that of thyme or rosemary. Its colour is a golden yellow.

When exposed to the air, it partly evaporates, and there remains a thick brown matter with a sharp bitterish taste, which at last also evaporates.

With alkalis, it forms a soap, which possesses all the characters of soaps made with volatile oils.

Alcohol dissolves it entirely; and when water is added to the solution it becomes milky, but no precipitate is produced †.

† *Ibid.* 159. These properties shew that this is a volatile oil, and consequently it is probable that camphor is composed of volatile oil and carbon.

508
Camphoric acid. Mr Kosegarten, by distilling nitric acid off camphor eight times successively, obtained an acid in crystals ‡, to which the name of *camphoric acid* has been given.

‡ *Kosegarten, de Camphora, &c.* 3785. His experiments have been repeated by Mr Bouillon La Grange. He mixed together 122,284 parts of camphor with 489,136 parts of nitric acid of the specific gravity 1,33, and distilled them. Much nitrous and carbonic acid gas were disengaged, and part of the camphor was sublimed; but part was converted into an acid. He returned the sublimed camphor into the retort, poured on it the same quantity of nitric acid as at first, and distilled again. This process he repeated till the whole camphor was acidified §. The quantity of camphoric acid obtained amounted to 53,498. The quantity of nitric acid was 2114,538.

§ *Ann. de Chim.* *ibid.*

509
Its properties. Camphoric acid thus obtained is in snow-white crystals, of the form of parallelepipedons ||.

¶ *Kosegarten.* These crystals effloresce in the air ¶.
¶ *La Grange.* Camphoric acid has a slightly acid bitter taste, and smell like that of saffron.

It reddens vegetable colours.

It is soluble in 200 parts of cold water, according to Kosegarten; in 96 parts of water at the temperature of 60°, according to La Grange. Boiling water dissolves $\frac{1}{2}$ th of its weight*.

* *Kosegarten.* According to Kosegarten, it is insoluble in alcohol;

according to La Grange, alcohol dissolves it, and when the solution is left in contact with the air of the atmosphere, the acid crystallizes. It is not precipitated from its solution in alcohol by the addition of water †.

† *Bouillon La Grange, Ann. de Chim.* xxvii. When this acid is placed on ignited coals, it emits a

dense aromatic fume, and is entirely dissipated. By a gentler heat, it melts, and is sublimed. If it be put into a heated porcelain tube, and oxygen gas be passed through it, the acid does not undergo any change, but is sublimed.

Suberic Acid.

By mere distillation, it first melts and then sublimes; by which process its properties are in some respect changed. It no longer reddens the tincture of turnsole, but acquires a brisk aromatic smell; its taste becomes less penetrating, and it is no longer soluble either in water or the sulphuric and muriatic acids. Heated nitric acid turns it yellow and dissolves it. Alcohol likewise dissolves it; and if this solution be left in contact with the air of the atmosphere, it crystallizes.

Camphoric acid does not produce any change in sulphur; alcohol and the mineral acids totally dissolve it; and so likewise do the volatile and the fat oils.

Camphoric acid does not precipitate lime from lime-water. It produces no change on the solution of indigo in sulphuric acid.

It forms combinations with the alkalis, earths, and metallic oxides, which are called *camphorates*.

Its affinities, as far as ascertained by La Grange, are as follows*:

Lime,
Potash,
Soda,
Barytes,
Ammonia,
Alumina,
Magnesia.

SECT. XXIII. Of Suberic Acid.

CORK, a substance too well known to require any description, is the bark of a tree which bears the same of suberic name. By means of nitric acid, Brugnatelli converted acid.

511
Discovery into an acid †, which has been called the *suberic acid*, † *Crell's* from *Suber*, the Latin name of the cork-tree. Several *Annals*, chemists affirmed that this acid was the oxalic, because 1787. it possessed several properties in common with it. These assertions induced Bouillon la Grange to undertake a set of experiments on suberic acid. These experiments, which have been published in the 23d volume of the *Annales de Chimie*, completely establish the peculiar nature of suberic acid, by shewing that it possesses properties different from those of every other acid.

512
Method of preparing To prepare it, a quantity of found cork grated down small is to be put into a retort, six times its weight of nitric acid of the specific gravity 1,261 poured upon it.

it, and the mixture distilled by means of a gentle heat. Red vapours are immediately discharged; the cork swells up and becomes yellow, and as the distillation advances, it sinks to the bottom, and its surface remains frothy. If that froth does not form properly, it is a proof that some part of the cork has escaped the action of the acid. In that case, after the distillation is pretty far advanced, the acid which has passed into the receiver is to be poured back into the retort, and the distillation continued till no more red vapours can be perceived; and then the retort is to be immediately taken out of the sand-bath, otherwise its contents would become black and adhere to it. While the matter contained in the retort is hot, it is to be poured into a glass vessel, placed upon a sand-bath over a gentle fire, and constantly stirred with a glass rod. By this means it becomes gradually

Suberic Acid.

Suberic Acid.

gradually thick. As soon as white vapours, exciting a tickling in the throat, begin to disengage themselves, the vessel is removed from the bath, and the mass continually stirred till it is almost cold.

By this means an orange-coloured mass is obtained of the consistence of honey, of a strong and sharp odour while hot, but having a peculiar aromatic smell when cold.

On this mass twice its weight of boiling water is to be poured, and heat applied till it becomes liquid; and then that part of it which is insoluble in water is to be separated by filtration (N). The filtered liquor becomes muddy; on cooling it deposits a powdery sediment, and a thin pellicle forms on its surface. The sediment is to be separated by filtration, and the liquor reduced to a dry mass by evaporating in a gentle heat. This mass is *suberic acid*. It is still a little coloured, owing to some accidental mixture, from which it may be purified either by saturating it with potash and precipitating it by means of an acid, or by boiling it along with charcoal powder.

513
Its properties.

Suberic acid thus obtained is not crystallizable, but when precipitated from potash by an acid, it assumes the form of a powder; when obtained by evaporation it forms thin irregular pellicles.

Its taste is acid and slightly bitter; and when dissolved in a small quantity of boiling water it acts upon the throat, and excites coughing.

It reddens vegetable blues; and when dropped into a solution of indigo in sulphuric acid (*liquid blue*, as it is called in this country), it changes the colour of the solution, and renders it green.

Water at the temperature of 60° or even 70° dissolves

only $\frac{1}{57,6}$ part of its weight of suberic acid, and if the acid be very pure, only $\frac{1}{137}$ th part: boiling water, on the contrary, dissolves half its weight of it.

When exposed to the air, it attracts moisture, especially if it be impure.

When exposed to the light of day, it becomes at last brown; and this effect is produced much sooner by the direct rays of the sun.

When heated in a matrass, the acid sublimes, and the inside of the glass is surrounded with zones of different colours. If the sublimation be stopped at the proper time, the acid is obtained on the sides of the vessel in small points formed of concentric circles. When exposed to the heat of the blow-pipe on a spoon of platinum, it first melts, then becomes pulverulent, and at last sublimes entirely with a smell resembling that of sebatic acid (o).

It is not altered by oxygen gas:—the other acids do not dissolve it completely. Alcohol develops an aromatic odour, and an ether may be obtained by means of this acid.

It converts the blue colour of nitrate of copper to a green; the sulphate of copper also to a green; green sulphate of iron to a deep yellow; and sulphate of zinc to a golden yellow (p).

It has no action either on platinum, gold, or nickel; but it oxidates silver, mercury, copper, lead, tin, iron, bismuth, arsenic, cobalt, zinc, antimony, manganese, and molybdenum.

514
Its action on other bodies.

With alkalis, earths, and metallic oxides, it forms compounds known by the name of *suberats*.

Its affinities are as follows (Q):

T t 2

515
Its affinities.
Barytes,

(N) When this substance is put into a matrass, water poured on it, and heat applied, it melts; and when the vessel is taken from the fire and allowed to cool, one part of it, which is of the consistence of wax, swims on the surface of the water, and another part precipitates to the bottom of the vessel, and assumes the appearance of a whitish magma. When this magma is separated by filtration, and washed and dried, a white tasteless powder is obtained, mixed with ligneous threads, soluble in acids and alkalis.

(o) An acid which shall be afterwards described.

(p) Owing perhaps to the presence of a little iron in the sulphat.

(Q) The place which the suberic acid occupies in the affinities of the alkalis, earths, and metallic oxides, as far as this subject has been investigated by Bouillon La Grange, will appear by the following Tables:

POTASS.

Sulphuric acid,
Nitric,
Muriatic,
Suberic.

ALUMINA.

Sulphuric acid,
* * *
Oxalic,
Suberic.

OXIDE OF MERCURY.

Sebacic acid,
* * *
Nitric,
Suberic.

SODA.

Sulphuric acid,
Nitric,
Muriatic,
Suberic.

OXIDE OF TIN.

* * *
Muriatic,
Suberic.

OXIDE OF LEAD.

* * *
Muriatic,
Suberic.

BARYTES.

Sulphuric acid,
Oxalic,
* * *
Muriatic,
Suberic.

OXIDE OF SILVER.

Muriatic,
* * *
Sulphuric,
Suberic.

OXIDE OF COPPER.

* * *
Sulphuric,
Suberic.

LIME.

Oxalic acid,
Sulphuric,
* * *
Muriatic,
Suberic.
MAGNESIA as lime.

OXIDE OF MOLYBDENUM.

Suberic acid.

OXIDE OF ANTIMONY.

* * *

Muriatic,
Suberic,
MANGANESE the same.

OXIDE

Laccic
Acid.Barytes,
Potafs,
Soda,
Lime,
Ammonia,
Magnesia,
Alumina*.Laccic
Acid.* Ann. de
Chim. xxiii.
42.516
Its composition.

Mr Bouillon La Grange, to whom we are indebted for all the facts relative to this acid, supposes that it is composed of oxygen, hydrogen, and carbon: but Mr Jamefon, in consequence of the result of a series of experiments which he made on charcoal, has been led to suspect that it consists entirely of carbon and oxygen. He found, that by the action of nitric acid upon charcoal, a brown, bitter, deliquescent mass was formed, soluble in water, alcohol, and alkalis, and which emitted, particularly when heated, a very fragrant odour. This matter was more or less soluble in water according to the time that it had been exposed to the action of the acid. When the nitric acid used was concentrated, and considerable in quantity, part of the charcoal was converted into an acid, which possessed the characters of the suberic †.

† Jamefon's
Mineralogy
of Sbeiland
and Arran,
p. 167.

These facts are curious, and may extend our knowledge of the nature of vegetable acids, but they are insufficient to prove the absence of hydrogen in suberic acid, because charcoal cannot easily be procured perfectly free from hydrogen, and because several of the properties of suberic acid indicate the presence of hydrogen in it, its becoming brown, for instance, when exposed to the light. Mr Jamefon has observed, that the acid which exists ready formed in peat possesses the properties of suberic acid.

SECT. XXIV. Of Laccic Acid.

517
Discovery
of white
lac.

ABOUT the year 1786, Dr Anderson of Madras mentioned, in a letter to the governor and council of that place, that nests of insects, resembling small cowry shells, had been brought to him from the woods by the natives, who eat them with avidity. These supposed nests he soon afterwards discovered to be the coverings of the females of an undescribed species of coccus, which he shortly found means to propagate with great facility on several of the trees and shrubs growing in his neighbourhood (R).

On examining this substance, which he called *white lac*, he observed in it a very considerable resemblance to bees wax; he noticed also, that the animal which secretes it provides itself by some means or other with a small quantity of honey, resembling that produced by our bees; and in one of his letters he complains, that

the children whom he employed to gather it were tempted by its sweetness to eat so much of it as materially to reduce the produce of his crop. Small quantities of this matter were sent into Europe in 1789, both in its natural state and melted into cakes; and in 1793 Dr Pearfon, at the request of Sir Joseph Banks, undertook a chemical examination of its qualities, and his experiments were published in the Philosophical Transactions for 1794.

A piece of white lac, from 3 to 15 grains in weight, is probably produced by each insect. These pieces are of a grey colour, opaque, rough, and roundish. When white lac was purified by being strained through muslin, it was of a brown colour, brittle, hard, and had a bitterish taste. It melted in alcohol, and in water of the temperature of 145°. In many of its properties it resembles bees wax, though it differs in others; and Dr Pearfon supposes that both substances are composed of the same ingredients, but in different proportions.

Two thousand grains of white lac were exposed in such a degree of heat as was just sufficient to melt them. As they grew soft and fluid, there oozed out 550 grains of a reddish watery liquid, which smelled like newly baked bread (S). To this liquid Dr Pearfon has given the name of *laccic acid* *.

It possesses the following properties: It turns paper stained with turnsole to a red colour. After being filtered, it has a slightly saltish taste with bitterness, but is not at all sour.

When heated, it smells precisely like newly baked hot bread.

On standing, it grows somewhat turbid, and deposits a small quantity of sediment.

Its specific gravity at the temperature of 60° is 1,025.

A little of it having been evaporated till it grew very turbid, afforded on standing small needle-shaped crystals in mucilaginous matter.

Two hundred and fifty grains of it were poured into a very small retort and distilled. As the liquor grew warm, mucilage-like clouds appeared; but as the heat increased they disappeared again. At the temperature of 200°, the liquor distilled over very fast: A small quantity of extractive matter remained behind. The distilled liquor while hot smelled like newly baked bread, and was perfectly transparent and yellowish. A shred of paper stained with turnsole, which had been put into the receiver, was not reddened; nor did another which had been immersed in a solution of sulphat of iron, and also placed in the receiver, turn to a blue colour upon being moistened with the solution of potafs (T).

About

OXIDE OF IRON.

* * *

Sulphuric,
Suberic.

COBALT and ZINC the same with arsenic.

OXIDE OF BISMUTH.

* * *

Muriatic,
Suberic.

OXIDE OF ARSENIC.

* * *

Nitric acid,
Suberic.

(R) The Chinese collect a kind of wax, which they call *pe-la*, from a coccus, deposited for the purpose of breeding on several shrubs, and manage it exactly as the Mexicans manage the cochineal insect. It was the knowledge of this that induced Dr Anderson to attempt to propagate his insect.

(S) The same liquid appears on pressing the crude lac between the fingers; and we are told, that when newly gathered it is replete with juice.

(T) A proof that the acid was not the prussic.

518

Its analysis.

* Pearfon's
Transl. of
the Chemical
Nomenclature.519
Properties
of laccic
acid.

Laccic Acid.

About one hundred grains of this distilled liquid being evaporated till it grew turbid, after being set by for a night, afforded acicular crystals, which under a lens appeared in a group not unlike the umbel of parsley. The whole of them did not amount to the quarter of a grain. They tasted only bitterish.

Another 100 grains being evaporated to dryness in a very low temperature, a blackish matter was left behind, which did not entirely disappear on heating the spoon containing it very hot in the naked fire; but on heating oxalic acid to a much less degree, it evaporated and left not a trace behind.

Carbonat of lime dissolved in this distilled liquid with effervescence. The solution tasted bitterish, did not turn paper stained with turnsole red, and on adding to it carbonat of potash a copious precipitation ensued. A little of this solution of lime and of alkali being evaporated to dryness, and the residuum made red hot, nothing remained but carbonat of lime and carbonat of potash.

This liquid did not render nitrat of lime turbid, but it produced turbidness in nitrat and muriat of barytes.

To five hundred grains of the reddish-coloured liquor obtained by melting white lac, carbonat of soda was added till the effervescence ceased, and the mixture was neutralised; for which purpose three grains of the carbonat were necessary. During this combination a quantity of mucilaginous matter, with a little carbonat of lime, was precipitated. The saturated solution being filtrated and evaporated to the due degree, afforded on standing deliquescent crystals, which on exposure to fire left only a residuum of carbonat of soda.

Lime-water being added to this reddish-coloured liquor produced a light purple turbid appearance; and on standing there were clouds just perceptible.

Sulphuret of lime occasioned a white precipitation, but no sulphurated hydrogen gas was perceptible by the smell.

Tincture of galls produced a green precipitation.

Sulphat of iron produced a purplish colour, but no precipitation; nor was any precipitate formed by the addition first of a little vinegar, and then of a little potash, to the mixture.

Acetite of lead occasioned a reddish precipitation, which redissolved on adding a little nitric acid.

Nitrat of mercury produced a whitish turbid liquor.

Oxalic acid produced immediately the precipitation of white acicular crystals, owing probably to the presence of a little lime in the liquid.

Tartrate of potash produced a precipitation not unlike what takes place on adding tartarous acid to tartrate of potash (v); but it did not dissolve again on adding potash.

Such were the properties of this acid discovered by Dr Pearson. Its destructibility by fire, and its affording carbon, distinguish it from all the acids described in this article before the acetous; and its peculiar smell when heated, its precipitating tartrate of potash without forming tartar, its bitterish taste, and its being con-

verted into vapour at the temperature of 200°, distinguish it from all the acids hitherto examined*.

Pyromucous Acid.

SECT. XXV. Of Pyromucous Acid.

Pyromucous (v) acid is procured by distilling sugar or any of the sweet juices. As they foam very much, the retort should be large, and seven-eighths of it empty. A prodigious quantity of carbonic acid and carbonated hydrogen gas is disengaged: A very thin light coal remains behind in the retort. Morveau found the glass of the retort attacked. The quantity of sugar distilled was 2304 grains; the coal weighed 982 grains. There were 428 grains of a brown liquor in the receiver, consisting mostly of an acid phlegm. This redistilled gave 313 grains of a liquor almost limpid, the specific gravity of which was 1,0115 at the temperature of 77°. It reddened blue paper. This acid may be concentrated by freezing, or by combining it with some base, potash, for instance, and decomposing the compound by a stronger acid, as, for example, the sulphuric.

It has a very sharp taste. When exposed to heat in open vessels, it evaporates, leaving a brown spot. It is tilled in close vessels, it leaves charcoal behind it.

It does not dissolve gold as Schrickel and Lemery and several other chemists affirmed.

It does not attack silver nor mercury, nor even their oxides †. It corrodes lead, and forms styptic and long crystals. Copper forms with it a green solution: With iron it forms green crystals; with antimony and zinc greenish solutions.

The compounds which it forms are called *pyromucites*. Its affinities, according to Morveau, are as follows:

- Potash,
- Soda,
- Barytes,
- Lime,
- Magnesia,
- Ammonia,
- Alumina,
- Jargonia ‡.
- Metallic oxides as in *sulph. acid*,
- Water,
- Alcohol.

521
Combinations, and affinities.

† Vauquelin, Ann. de Chim. xxii. 208.

SECT. XXVI. Of Pyro-lignous Acid.

It is well known that the smoke of burning wood is exceedingly offensive to the eyes: And chemists have long ago observed, that an acid might be obtained by distilling wood.

It is to Mr Goettling, however, and to the Dijon academicians, who repeated his experiment, that we are indebted for what knowledge we possess of the peculiar properties of this acid, which, because it is obtained from wood by means of fire, has been called the *pyro-lignous acid* (w). It appears to be the same from whatever kind of wood it is obtained.

Mr Goettling filled an iron retort with pieces of birch tree bark, and obtained by distillation a thick, brown, very empyreumatic acid liquor. This liquor he allowed

(v) On this addition, tartar, or acidulated tartrate of potash, is formed, which precipitates, because it is very little soluble in water. The addition of potash dissolves it again.

(v) Morveau called this acid *syrupous acid*.

(w) Goettling called it *lignous acid*.

Pyro-lignous Acid.

allowed to remain at rest for three months, and then separated from it a quantity of oil which had risen to the top. By distilling this liquor again, and then saturating it with potash, and evaporating to dryness, he obtained a brown saline mass; which, by being redissolved in water, and evaporated, yielded greyish white crystals: These crystals were composed of pyro-lignous acid and potash. He poured upon them, by little and little, a quantity of sulphuric acid; and by applying a gentle heat, the pyro-lignous acid came over in considerable purity*.

* Crell's Journal, 1779.

524
Its properties, combinations, and affinities.

The Dijon academicians obtained this acid from beech wood: by distilling 55 ounces, they procured 17 ounces of acid; which, when rectified by a second distillation, was of the specific gravity 1,02083.

It reddens vegetable colours: when exposed to a strong heat, it takes fire and is destroyed. It unites very well with alcohol.

Its compounds are called *pyro-lignites*.

Its affinities, as fixed by Mr Eloy Bourcier de Clerveaux and Mr de Morveau, are as follows:

Lime,
Barytes,
Potash,
Soda,
Magnesia,
Ammonia,
Oxide of zinc,
—— manganese,
—— iron,
—— lead,
—— tin,
—— cobalt,
—— copper,
—— nickel,
—— arsenic,
—— bismuth,
—— mercury,
—— antimony,
—— silver,
—— gold,
—— platinum,
Alumina,
Jargonite †?

† Vauquelin, Ann. de Chim. xxii. 208.

SECT. XXVII. Of Pyro-tartarous Acid.

AN acid may also be obtained by distilling tartar; it is called *pyro-tartarous acid*.

525
Properties of pyro-tartarous acid.

It has an empyreumatic taste and odour; reddens the tincture of turnsole; but has no effect on that of violets. Little is known concerning this acid, except that many of its properties are the same with those of the pyro-lignous; and Morveau conjectures that, if properly purified, it would probably be discovered to be the same with it.

The compounds which it forms are called *pyro-tartarites*.

Its affinities are unknown. Morveau supposes that they are the same with those of the pyro-lignous acid.

526
Vegetable acids,

THE 18 preceding acids are all (except the lactic and saccholactic) denominated *vegetable acids*, because

they are obtained from vegetable substances. We have placed the lactic and saccholactic acids in the same class; because they bear a strong resemblance to vegetable acids, and because they are evidently composed of the same ingredients with them.

Vegetable Acids.

Vegetable acids are distinguished from all the acids described in the beginning of this chapter, by their destructibility by fire. 527 Destroyed by fire.

There is no circumstance in chemistry which has attracted greater attention than the possibility of converting the various vegetable acids into each other by means of different processes. To explain what passes during these processes, it would be necessary to know exactly the component parts of every vegetable acid, the manner in which these acids are combined, and the affinities which exist between each of their ingredients. This, however, is very far from being the case at present. Though a vast number of experiments have been made on purpose to throw light on this very point, the difficulties which were to be encountered have been so great, that no accurate results have yet been obtained. 528 Convertible into each other.

It follows from these experiments, that all the vegetable acids are composed, chiefly at least, of oxygen, hydrogen, and carbon; but that the proportions differ in every individual acid. We say chiefly, because it has been suspected from some phenomena, that one or two of these acids contain besides a little azot. Let us take a view of what is at present known of the composition of these acids in their order. 529 Inquiry into the proportions of their ingredients.

1. As to carbonic acid, its composition has been ascertained with tolerable accuracy; it consists of about 28 parts of carbon and 72 of oxygen.

2. By distilling 7680 grains of acetite of potash, Dr Higgs obtained the following products*:

* Higgs on Acetous Acid, p. 26.

Potash,	- - - -	3862,994 grains.
Carbonic acid gas,	- - - -	1473,564
Carbonated hydrogen gas,	- - - -	1047,6018
Residuum, consisting of carbon,	- - - -	78,0000
Oil,	- - - -	180,0000
Water,	- - - -	340,0000
Deficiency (x),	- - - -	726,9402

This deficiency Dr Higgs found to be owing to a quantity of water and oil which is carried off by the elastic fluids, and afterwards deposited by them. He calculated it, in the present case, at 700 grains of water and 26,9402 grains of oil. Now, since acetite of potash is composed of acetous acid and potash, and since the whole of the potash remained unaltered, it follows that the acetous acid was converted into carbonic acid gas, carbonated hydrogen gas, carbon, oil, and water; all of which are composed of oxygen, hydrogen, and carbon.

Now 1473,564 gr. of carbonic acid gas are composed of 1060,966 gr. of oxygen, and 415,598 gr. of carbon.

1047,6018 grains of carbonated hydrogen gas, from a comparison of the experiments of Dr Higgs and Lavoisier, may be supposed to consist of about 714,6008 grains of carbon, and 333,0010 of hydrogen.

200,9402 grains of oil contain 163,4828 grains of carbon and 43,4574 grains of hydrogen.

1040 grains of water contain 884 grains of oxygen and 156 grains of hydrogen.

Therefore

(x) For 29,1 grains of oxygen gas had also disappeared from the air of the vessels.

Vegetable
Acids.

Therefore 3817,006 grains of acetous acid are composed of 1944,966 — 29,1 = 1915,866 grains of oxygen, 532,4584 grains of hydrogen, and 1368,6816 grains of carbon. Consequently 100 parts of acetous acid are composed of

50,19 oxygen,
13,94 hydrogen,
35,87 carbon.

100,00

These numbers can only be considered as approximations to the truth; for the object of Dr Higgens was not to ascertain the proportions of the ingredients which compose acetous acid; and therefore his experiments were not conducted with that rigid accuracy which would have been necessary for that purpose.

It is extremely probable, that during the acetous fermentation, or the conversion of alcohol into acetous acid, a quantity of water is formed*; and it is certain that oxygen is absorbed. It follows from this that acetous acid contains more carbon and less hydrogen than alcohol. Now we have reason, from Lavoisier's experiments, to believe that alcohol is formed of

51,72 oxygen,
18,40 hydrogen,
29,88 carbon.

Lavoisier supposes that this acid contains also azot.

3. Acetic acid is supposed to consist of the same base with acetous acid, combined with a larger proportion of oxygen; we would rather say, that it is acetous acid combined with oxygen.

4. When oxalic acid is distilled with six times its weight of sulphuric acid, the products are acetous acid, sulphurous acid, carbonic acid gas, and sulphuric acid remains in the retort †. Hence it follows, that oxalic acid contains more carbon than acetous acid; but that it is composed of the same ingredients. It has been supposed that oxalic acid is composed of sugar and oxygen. Now sugar, according to Lavoisier, is composed of

Hydrogen,	-	-	-	-	8
Oxygen,	-	-	-	-	64
Carbon,	-	-	-	-	28

These proportions are rather unfavourable to that notion; at least if any dependence can be put in the composition of acetous acid as deduced from the experiments of Dr Higgens.

5. Hermstadt dissolved four ounces of tartarous acid in 16 ounces of water, and kept the solution in a vessel covered with paper in a warm place. In three months the taste of the solution was changed, and the air in the upper part of the vessel was found to be carbonic acid. In six months the solution was converted into acetous acid. It follows, from this experiment, that tartarous acid contains more carbon than acetous acid, and that their ingredients are the same. If any doubts should remain, the following experiment is sufficient to remove them. Weftrum mixed strong sulphuric acid with tartarous acid, and added manganese; acetous acid was produced, and a great quantity of carbonic acid gas was disengaged. When nitric acid is distilled off tartarous acid, it is converted into oxalic acid, as Scheele first proved. Hence it has been supposed by some, that oxalic acid differs from tartarous merely in containing more oxygen: but this is very far indeed from be-

ing proved. According to Hassenfratz, tartarous acid contains a considerable quantity of azot.

6. When citrat of lime is allowed to remain in a bottle slightly corked along with a little alcohol, the citric acid is gradually converted into acetous acid*. * *Stabl.* Weftrum converted it into oxalic acid by means of nitric acid.

7. Malic acid was converted into oxalic by means of nitric acid by Scheele. It has been supposed to contain more oxygen than oxalic acid. Some of it is always formed during the common process of converting sugar into oxalic acid. Were we to judge from an experiment, which, however, was not performed with sufficient accuracy, we would conclude that the base of malic acid is gum; for by distilling two parts of weak nitric acid off one part of gum in a very small heat, we obtained a quantity of acid more in weight than the gum, which exhibited several of the distinguishing properties of malic acid. It was exceedingly light, white, and spongy, and attracted water very quickly from the atmosphere, and could not afterwards be brought by evaporation to its former state.

8. Scheele converted lactic acid into acetous by mere exposure to the atmosphere, and found that a quantity of carbonic acid was disengaged. Hence this acid is merely the acetous with a smaller proportion of carbon.

9. The gallic acid, we have seen, contains more carbon than any of the others.

10. Nothing is known concerning the composition of the benzoic and succinic acids. Hermstadt says he converted benzoic acid to oxalic by means of nitric acid; but Morveau did not observe that any change was produced.

11. The base of camphoric is probably camphor.

Though these eighteen are the only acids which have hitherto been examined with attention, it cannot be doubted that the number of vegetable acids, either existing naturally, or at least capable of being formed by art, is considerably greater. Morveau has lately ascertained, that the red colours of flowers are owing to acids: This had already been conjectured by Linnæus.

SECT. XXVIII. Of Prussic Acid.

ABOUT the beginning of the present century, Diesbach, a chemist of Berlin, wishing to precipitate a solution of cochineal mixed with a little alum and sulphat of iron, borrowed from Dippel some potash, from which that chemist had distilled several times his animal oil. On pouring in the potash, Diesbach was surprised to see, instead of the red precipitate which he had expected, a beautiful blue powder falling to the bottom of the vessel. By reflecting on the materials which he had employed, he easily discovered the method of procuring the blue powder at pleasure †. This powder was called *Prussian Blue*, from the place where it was discovered. It was announced in the Berlin Memoirs for 1710; but the process was concealed, because it had become a lucrative article of commerce. A method of preparing it, however, was published by Woodward in the Philosophical Transactions for 1724, which he said he had got it from one of his friends in Germany. This method was as follows: Detonate together 4 ounces of nitre and as much tartar, in order to procure an extemporaneous alkali; then add 4 ounces of dried bullock's blood, mix the-

Prussic
Acid.* Hermstadt,
Crell's An-
nals, 1786.† Crell,
Jour. de
Chim. 1785.

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Discovery
of Prussian
blue.† Stabl's
300 Expe-
riments.

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Method of
preparing.

Prussic Acid.

the ingredients well together, and put them into a crucible covered with a lid, in which there is a small hole; calcine with a moderate fire till the blood emits no more smoke or flame capable of blackening any white body exposed to it: increase the fire towards the end, so that the whole matter contained in the crucible shall be moderately but sensibly red. In this state throw it into two pints of water, and boil it for half an hour. Decant off this water, and continue to pour on more till it come off insipid. Add all these liquids together, and boil them down to two pints. Dissolve two ounces of sulphat of iron and eight ounces of alum in two pints of boiling water; mix this with the former liquor while both are hot. An effervescence takes place, and a powder is precipitated of a green colour mixed with blue. Separate this precipitate by filtration, and pour muriatic acid upon it till it becomes of a beautiful blue; then wash it with water and dry it.

Different explanations were given of the nature of this precipitate by different chemists. All of them acknowledged that it contained iron, but to account for the colour was the difficult point. Brown, and Geoffroy, and Neumann, discovered in succession, that a great many other animal substances besides blood communicated to alkalies the property of forming Prussian blue. Macquer undertook an examination of this substance, and published the result of his experiments in the Memoirs of the French Academy for 1752.

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Its composition discovered by Macquer.

He observed that, when alkali is added to a solution of iron in any acid, the iron is precipitated of a yellow colour, and soluble in acids; but if iron be precipitated from an acid by an alkali prepared as above described, by calcination with blood (which has been called a *Prussian alkali*), it is of a green colour. Acids dissolve only a part of this precipitate, and leave behind an insoluble powder which is of an intense blue colour. The green precipitate therefore is composed of two different substances, one of which is Prussian blue; the other, as he ascertained by experiment, is the brown or yellow oxide of iron: and the green colour is owing to the mixture of the blue and yellow substances. When heat is applied to the insoluble precipitate, its blue colour is destroyed, and it becomes exactly similar to common oxide of iron. It is composed therefore of iron and some other substance, which heat has the property of driving off. If this insoluble precipitate be boiled with a very pure alkali, it loses its blue colour also, and at the same time the alkali acquires the property of precipitating of a blue colour solutions of iron in acids, or it has become precisely the same with the Prussian alkali. Prussian blue, therefore, is composed of iron and something which a pure alkali can separate from it, something which has a greater affinity for alkali than for iron. By boiling a quantity of alkali with Prussian blue, it may be completely saturated with this something, which we shall call *colouring matter*, and then it has lost all its alkaline properties. No acid can separate this colouring matter from iron after it is once united with it. When iron dissolved in an acid is mixed with an alkali saturated with the colouring matter, a double decomposition takes place, the acid unites with the alkali, and the colouring matter with the iron, and forms Prussian blue. The reason that, in the common method of preparing Prussian blue, a quantity of yellow oxide is precipitated, is, that there is not a sufficient quantity of co-

louring matter (for the alkali is never saturated with it) to saturate all the iron displaced by the alkali; a part of it therefore is mixed with Prussian blue. Muriatic acid dissolves this oxide, carries it off, and leaves the blue in a state of purity. Such were the conclusions which Macquer drew from his experiments; experiments which not only discovered the composition of Prussian blue, but threw a ray of light on the nature of affinities, which has contributed much towards the advancement of that important branch of chemistry.

Prussic Acid.

The nature of the colouring matter, however, was still unknown. Macquer himself supposed that it was pure phlogiston; but the opinion was untenable. He had shewn that it possessed the property of forming neutral salts, and therefore Bergman and Morveau suspected that it was an acid.

Scheele undertook the task of examining its nature, and published the result of his experiments in the Stockholm Transactions for 1782.

He observed that the Prussian alkali, after being exposed for some time to the air, lost the property of forming Prussian blue; the colouring matter must therefore have left it.

He put a small quantity of it into a large glass globe, corked it up, and kept it some time; but no change was produced either in the air or the Prussian alkali. Something must therefore displace the colouring matter when the alkali is exposed to the open air, which is not present in a glass vessel. Was it carbonic acid gas? To ascertain this, he put a quantity of Prussian alkali into a glass globe filled with that gas, and in 24 hours the alkali was incapable of producing Prussian blue. It is therefore carbonic acid gas which displaces the colouring matter. He repeated this experiment with this difference, that he hung in the globe a bit of paper which had been previously dipped into a solution of sulphat of iron, and on which he had let fall two drops of an alkaline lixivium, in order to precipitate the iron. This paper was taken out in two hours, and became covered with a fine blue on adding a little muriatic acid. Carbonic acid, then, has the property of separating the colouring matter from alkali without decomposing it.

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Decomposed by Scheele.

He found also that other acids produced the same effect. The colouring matter then may be obtained perhaps in a separate state. He accordingly made a number of attempts to procure it, and at last discovered the following process: He boiled together for some minutes two ounces of Prussian blue in powder, one ounce of the red oxide of mercury, and six ounces of water; then passed the whole through a filter, and washed the residuum with two ounces of boiling water. The oxide of mercury has a greater affinity for the colouring matter than the oxide of iron; it therefore unites with it, and forms with it a salt soluble in water. The iron remains behind upon the filter, and the liquid is a solution of the colouring matter combined with mercury. He poured this solution upon half an ounce of pure iron filings, and added at the same time three grains of sulphuric acid. The iron separates the oxygen from the mercury, in order to combine with the sulphuric acid; the mercury is precipitated in its metallic state, and leaves behind it a quantity of sulphat of iron and of colouring matter dissolved in water, but not combined, as the colouring matter is unable to separate the iron from the acid.

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The colouring matter separated.

He then distilled in a gentle heat; the colouring matter is unable to separate the iron from the acid.*

* Berthollet, Ann. de Chimie, i. ter 30.

Prussic
Acid.Prussic
Acid.

ter came over by the time that one-fourth of the liquor had passed into the receiver. It was mixed, however, with a small quantity of sulphuric acid; from which he separated it by distilling a second time over a quantity of carbonate of lime. The sulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, because carbonic acid has a stronger affinity for lime than it has. Thus he obtained the colouring matter in a state of purity.

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Its compo-
nent parts.

It remained now to discover its component parts. He formed a very pure Prussian blue, which he distilled, and increased the fire till the vessel became red. The small quantity of water which he had put into the receiver contained a portion of the blue colouring matter and of ammonia; and the air of the receiver consisted of azot, carbonic acid gas, and the colouring matter. He concluded from this experiment, that the colouring matter was composed of ammonia and carbon. He mixed together equal quantities of pounded charcoal and potash, put the mixture into a crucible, and kept it red hot for a quarter of an hour: he then added a quantity of sal ammoniac in small pieces, which he pushed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceased to give out vapours of ammonia, and then threw it into a quantity of water. The solution possessed all the properties of the Prussian alkali. Thus Mr Scheele succeeded in forming the colouring matter; and it was considered as proved that it was composed of ammonia and carbon.

But after the publication of Scheele's experiments, it was discovered that ammonia itself is composed of azot and hydrogen. It became therefore a question, Whether ammonia entered into the composition of this substance, or merely its ingredients? Whether it was composed of ammonia and carbon, or of azot, hydrogen, and carbon combined in a different manner? This point has been decided by the following experiments: Mr Clouet made a quantity of ammoniacal gas pass through a red hot porcelain tube filled with charcoal, and by this process formed a quantity of the colouring matter*. Here the temperature was so high that the ammonia must have been decomposed: and the colouring matter cannot be formed by combining ammonia and charcoal except at a temperature equally high. There is reason therefore to suppose that the ammonia is decomposed. When oxy-muriatic acid is mixed with the colouring matter, it communicates to it a quantity of oxygen, and causes it in consequence to assume very different properties. When a fixed alkali or lime is added to it in this state, it is immediately decomposed, and converted into ammonia and carbonic acid gas. The colouring matter in this state contains all the ingredients necessary to form these two substances, namely, azot, hydrogen, carbon, oxygen: but in order to induce the ingredients to form these two compounds, the assistance of an alkali or lime to combine with the carbonic acid is necessary; just as sulphur combines more easily with oxygen when united with an alkali or with iron than when separate †.

* Ann. de
Chim. xi.† Berthollet,
ibid. i.

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The colouring matter, then, which we shall henceforth call the *Prussic acid*, is composed of azot, hydrogen, and carbon; but the proportions of these ingredients have not yet been determined. It is considered as an acid, though the presence of oxygen has not been proved, because it has the property of forming neutral salts with the same bases as other acids.

The Prussic acid is exceedingly volatile, and evidently capable of existing in a gaseous state. It has a peculiar odour, not disagreeable, and which has been compared to the flowers of the peach. It has a sweetish and somewhat hot taste, and excites cough*.

It has no affinity for alumina nor for alcohol †.

This substance differs exceedingly in its action from all other acids.

It is capable of combining, like them, with earths, alkalis, and metallic oxides, and of forming compounds which have been denominated *Prussiates*. But it enters much more readily into triple compounds with alkalis or earths, and metallic oxides, than into combinations with earths or alkalis separately; and though its affinity appears to be greater for alkalis and earths than for metallic oxides, yet when in a free or gaseous state it does not enter into combinations with earths or alkalis without difficulty, and it is separated from them much more easily than from metallic oxides. Mere exposure to the light of the sun, or to a heat of 110°, is sufficient for that purpose.

Its affinities are supposed to be as follows:

Potash,
Soda,
Ammonia,
Lime,
Barytes,
Magnesia,
Oxide of zinc,
—— iron,
—— manganese,
—— cobalt,
—— nickel,
—— lead,
—— tin,
—— copper,
—— bismuth,
—— antimony,
—— arsenic,
—— silver,
—— mercury,
—— gold,
—— platinum (γ).

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Its affini-
ties.

SECT. XXIX. Of Formic Acid.

In the 15th century several botanists observed, with astonishment, that the flower of succory, when thrown into an ant hill, became as red as blood: But it was Mr S Fisher who first discovered that ants possessed a peculiar acid, which he obtained by distilling these animals. His experiments were published in the Philosophical Transactions for 1670. Though Hoffman afterwards

U u

repeated

(γ) We suspect that this is not the real order of the affinities of this acid; the metallic oxides ought probably to be placed before the alkalis and earths, and the metallic Prussiates ought to occupy the place which is at present filled by the metallic oxides. The reasons for this conjecture will appear afterwards. See Part III. chap. ii. sect. 23. of this article.

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Discovery
of formic
acid.

Formic Acid.

repeated his process, little was known concerning the nature of this acid till Margraf undertook its examination, and published his experiments in the Berlin Memoirs for 1749.

The species of ants from which the formic acid is obtained is the *formica rufa*, which reside most commonly in woods, or at least in elevated and dry places. They have been found to contain the greatest quantity of acid in the months of June and July. If at that season one of these animals be pressed upon paper tinged with turnsole, it changes the colour of it to a most lively red: they even sometimes stain it merely by crawling over it.

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Methods of obtaining it.

There are two methods of obtaining the formic acid, distillation and lixiviation.

When the first method is to be employed, the ants are to be washed clean, dried with a gentle heat, put into a retort, and distilled with a moderate heat, gradually increased till all the acid has come over. It is mixed with an empyreumatic oil, from which it is separated by passing it through a strainer previously moistened with water. By this process Messrs Ardviffon and Oehrn obtained from a pound of ants $7\frac{1}{2}$ ounces of acid, the specific gravity of which, at the temperature of 60° , was 1,0075*. Morveau obtained from 49 ounces of ants 23 ounces of pretty strong acid †. Margraf added a quantity of water; but it is evident that this serves merely to weaken the acid.

* *Dissert. on the Acid of Ants, 1777, in Baldinger's New Magazine for Arts.*
† *Encyc. Method. i. 61.*

When the other method is preferred, the ants are to be washed in cold water, put upon a clean linen cloth, and boiling water poured on them repeatedly till it can extract no more acid. The linen is then to be squeezed, and the several liquors mixed and filtrated. This method was first used by Ardviffon and Oehrn: they obtained from a pound of ants an acid liquor which had more specific gravity than common vinegar. It is to be purified from the oil which adheres to it by repeated distillations. After four distillations the empyreumatic oil still manifests its presence by its smell, but this smell vanishes if the acid be exposed for some time to the air; a quantity of essential oil, however, still remains, which cannot be separated. The specific gravity of the acid

‡ *Ardviffon and Oehrn, ibid.*

§ *Crell's Annals, 1784.*

541
Its properties.
|| *Ibid.*

¶ *Ardviffon, ibid.*

* *Ibid.*

‡ *Morveau, p. 62.*

thus rectified is 1,0011 †. Hermstadt employed a third method. He expressed the juice of dry ants, and by this means obtained from 2 lbs. of these animals 21 oz. 2 dr. of juice, which on distillation yielded a clear pure acid, equal in strength to very concentrated vinegar §.

This acid seems to be capable of assuming a gaseous form; at least Hermstadt observed, that when he put some of it into a bottle with a glass stopper, the stopper was frequently raised by an elastic fluid making its escape, and that after some days it had lost its smell ||. When this acid is boiled with nitric acid, a gas is extricated, which renders lime-water turbid, and has a very pungent odour ¶.

This acid has a strong but not unpleasant smell, a caustic taste, and when much diluted a pleasant acidity. When most concentrated, its specific gravity is 1,0453*.

One part of this acid, mixed with 75 parts of water, gives a faint red to syrup of violets; mixed with 430 parts of water, it reddens paper coloured with turnsole; mixed with 1300 parts of water, it produces no effect on the infusion of turnsole †. It mixes readily with alcohol.

It unites readily with the other acids. When boiled with sulphuric acid, it becomes black. White acrid vapours rise when the mixture becomes hot; and when it boils, a gas rises which unites with difficulty to water and lime-water; the formic acid is again obtained, but its quantity is diminished*.

Nitric acid decomposes it altogether, and is itself converted into nitrous acid. Muriatic acid does not alter it. Oxy-muriatic acts like nitric acid †.

Its compounds are called *formiats*.

Its affinities are the same with those given above for the Prussic acid.

Sebacic Acid.

* *Ibid.*† *Ibid.*542
Its compounds and affinities.

SECT. XXX. Of Sebacic Acid.

CHEMISTS had long suspected that an acid could be obtained from tallow, on account of the acrid nature of the fumes which it emitted at a high temperature; but it was M. Grutmacher who first demonstrated this acid in a dissertation *De Ossium Medulla*, published in 1748 †. Mr Rhodes mentioned it in 1753, and Segner published a dissertation on it in 1754, and Crell examined its properties very fully in two dissertations published in the *Phil. Transf.* for 1780 and 1782. It was called at first *acid of fat*, and afterwards *sebacic acid*.

It may be procured by heating together a mixture of suet and lime. Sebat of lime is formed, which may be purified by solution in water. It is then to be put into a retort, and sulphuric acid poured on it. Sebacic acid passes over on the application of heat.

Sebacic acid has an acid, sharp, bitterish taste, and a very pungent smell. It reddens tincture of litmus. 544
Its properties,

Heat causes it to assume a yellow colour.

It oxidates silver, mercury, copper, iron, lead, tin, zinc, antimony, manganese.

It does not act upon bismuth, cobalt, nickel. When mixed with nitric acid it dissolves gold.

Its compounds are called *sebats*.

Its affinities, according to Morveau, are as follows:

Barytes,
Potash,
Soda,
Lime,
Magnesia,
Ammonia,
Alumina,
Jargonia §,
Oxide of zinc,
———— manganese,
———— iron,
———— lead,
———— tin,
———— cobalt,
———— copper,
———— nickel,
———— arsenic,
———— bismuth,
———— mercury,
———— antimony,
———— silver.

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Compounds and affinities.§ *Vauquelin, Ann. de Chim. xxii. 208.*

SECT. XXXI. Of Bombyc Acid.

MR BOISSIER DE SAUVAGES observed, that the juice of the silkworm, in the disease called in France *muscade*, was acid; and Chauffier remarked, that the silkworm, after being converted into a butterfly, gives out

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Discovery of bombyc acid.

Zoonic
Acid.

a liquor which turns vegetable blues to a red. He found, that during the time that the animal was forming its cocoon, the acid was deposited in a reservoir near the anus. By means of a pair of scissars he collected some which reddened blue paper, united with alkalies with effervescence, and even attacked the scissars. He afterwards collected it by infusing the chrysalids in alcohol, which dissolved the acid, but left the impurities untouched.

This acid has never been examined with attention; so that almost all its properties are unknown.

SECT. XXXII. *Of Zoonic Acid.*

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Method of
obtaining
zoonic a-
cid.
* *Ann. de
Chim.* xxvi.
86.

MR BERTHOLLET has obtained a peculiar acid by distilling vegetable and animal substances, to which he has given the name of the *zoonic acid* *. He procured it by distilling the gluten of wheat, the yelt of beer, bones, and woollen rags; and concludes, therefore, that it may be produced by the distillation of all animal substances.

To obtain this acid pure, he mixed lime with the distilled liquid, after having separated the oil, which it always contains (for the product of the distillation of animal substances is chiefly oil and carbonat of ammonia.) He boiled this mixture till the carbonat of ammonia was exhale: he then filtered it, added a little more lime, and boiled it again till the smell of the ammonia had gone off entirely. The liquor, which now contained only zoonat of lime, he filtered again, and then added a little water impregnated with carbonic acid, in order to precipitate any lime which might happen to be dissolved in the liquid without being combined with the zoonic acid.

After concentrating the zoonat of lime, he mixed it with phosphoric acid, and distilled it in a retort. At a heat nearly equal to that of boiling water, the zoonic acid passes over in a state of purity.

548
Its proper-
ties.

The zoonic acid has an odour like that of meat when frying, and it is actually formed during that process. It has an austere taste.

It gives a red colour to paper tinged with turnsole.

With alkalies and earths it produces salts, which do not appear capable of crystallizing.

It forms a white precipitate in the solutions of acetite of lead and nitrat of mercury.

Part of the zoonic acid seems to be destroyed by the action of heat during the distillation of the zoonat of lime with phosphoric acid: for the liquor, which is in ebullition, becomes brown, and grows black at the end of the operation; hence Mr Berthollet concludes that the zoonic acid contains carbon. The zoonat of silver, when kept, becomes gradually brown; hence he concludes that the acid contains hydrogen. These conclusions he draws from a very ingenious theory of his, which has been already described in the article BLEACHING in this Supplement †.

† Berthollet,
*Ann. de
Chim.* xxvi.
549
Animal
acids.

The five preceding acids have obtained the name of *animal acids*, because they are all obtained from the animal kingdom. It can scarcely be doubted that a more accurate examination of animal substances will add considerably to the number of these acids.

SECT. XXXIII. *Of Arsenic Acid.*

ARSENIC acid, which was first discovered by Scheele, may be produced by simply mixing the white oxide of

arsenic with oxy-muriatic acid, and applying a heat sufficient to sublime the muriatic acid. The theory of this operation is evident: the white oxide has a greater affinity for oxygen than muriatic acid has; of course it combines with it, and is thus converted into arsenic acid, and the muriatic acid is easily sublimed by applying heat.

Arsenic
Acid.
550
Method of
obtaining
arsenic a-
cid.

Landriani has informed us, that this acid may be also formed by subliming several times successively the white oxide of arsenic, and taking care every time to renew the air. This process is equally simple; the oxide combines at a high temperature with the oxygen of the atmosphere.

This acid is exceedingly fixed. When exposed to the air it attracts humidity, and at last becomes liquid. At the temperature of 60° it dissolves in two-thirds of its weight of water. Its solution may be evaporated to dryness, and even converted into a glass, which attracts moisture from the air, and acts powerfully on the crucible.

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Its proper-
ties.

It is poisonous as well as the white oxide of arsenic*.

When exposed to a red heat, it is partly decomposed and converted into white oxide of arsenic †.

* Scheele.

It does not act upon gold, platinum, silver, mercury.

† *Id.*

It oxidates copper, iron, lead, tin, zinc, bismuth, antimony, cobalt, nickel, manganese, and arsenic, and in a very strong heat, mercury and silver.

According to Berthollet's experiments, arsenic acid is composed of eight parts of white oxide of arsenic and one part of oxygen.

Its compounds are called *arseniats*.

Its affinities are as follows:

Lime,
Barytes,
Magnesia,
Potash,
Soda,
Ammonia,
Oxide of zinc,
— manganese,
— iron,
— lead,
— tin,
— cobalt,
— copper,
— nickel,
— bismuth,
— mercury,
— antimony,
— silver,
— gold,
— platinum,
Alumina,
Jargonias ‡?
Water.

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Its com-
pounds and
affinities.

SECT. XXXIV. *Of Tungstic Acid.*

TUNGSTIC acid, or oxide of tungsten, was first discovered by Scheele; but the acid which he examined was not pure, being composed, as Mr Luyart has shewn, of nitric acid, ammonia, and tungstic acid. The real acid is insoluble in water, tasteless, and incapable of turning vegetable blues red till it has been first rendered

† Vauquelin,
*Ann. de
Chim.* xxii.
208.

553
Properties
of tungstic
acid.

Molybdic Acid. soluble by being partly combined with ammonia. It is of a beautiful yellow colour, which becomes blue when exposed to the light, or heated violently in close vessels. It does not recover its yellow colour except by calcination in the open air, and then increases in weight. When put into muriatic acid along with tin, zinc, or iron, the liquor becomes blue*. Treated with acetic acid, it becomes blue. When reduced to a glass with phosphat of soda, the blue colour appears and disappears according as the blue or yellow part of the flame is directed to it, as happens to manganese. Probably this blue substance is an oxide of tungsten with a smaller quantity of oxygen.

554
Its compounds are called *tungstats*.
Its affinities are as follows †:

Lime,
Barytes,
Magnesia,
Potafs,
Soda,
Ammonia,
Alumina,
Jargonina ‡?

† Vauquelin,
Ann. de
Chim. xxii.
208.

SECT. XXXV. Of Molybdic Acid.

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Properties of molybdic acid.
§ Bergman.
CONCRETE molybdic acid, first discovered by Scheele, is white, and has an acid but metallic taste. Its specific gravity is 3,75 ρ . It is not altered in the air. When heated in a crucible till it is beginning to melt, it experiences no alteration. It remains fixed even in a great fire as long as the crucible is covered; but the moment it is uncovered the acid rises unaltered in a white smoke. It dissolves in 570 parts of water. The solution reddens turnsole; nitric acid does not affect it, but sulphuric and muriatic acids dissolve it by the assistance of heat.

It may be prepared by treating the ore of molybdenum with nitric acid, and washing the acid when formed in water.

When combined with potafs, it forms a colourless salt.

Mixed with filings of tin and muriatic acid, it immediately becomes blue, and precipitates flakes of the same colour, which disappear after some time, if an excess of muriatic acid has been added, and the liquor assumes a brownish colour.

With the solution of nitrat of lead it forms a white precipitate, soluble in nitric acid.

When mixed with a little alcohol and nitric acid, it does not change its colour.

With a solution of nitrat of mercury, or of nitrat of silver, it gives a white flaky precipitate.

With the nitrat of copper it forms a greenish precipitate.

With solutions of sulphat of zinc, muriat of bismuth, muriat of antimony, nitrat of nickel, muriats of gold and platinum, it produces white precipitates when these solutions do not contain an excess of acid.

When melted with borax, it gives it a bluish colour.

Paper dipped in this acid becomes in the sun of a beautiful blue colour ‖.

‖ Vauquelin, Philosophical Magazine, i. 202.
Sulphur is capable of partly decomposing it by heat. Its compounds are called *molybdats*. Its affinities are unknown.

SECT. XXXVI. Of Chromic Acid.

Chromic Acid.

In the year 1770, Mr Pallas discovered in the gold mine of Beresof, near Ekaterimboung in Siberia, a mineral of a red colour, with a shade of yellow, crystallized in small acute angled quadrangular prisms, sometimes smooth, sometimes longitudinally streaked, and often hollow. Mr Macquart, professor of medicine at Paris, who in 1783 had been sent to the north by the French government in order to collect mineralogical information, brought with him a quantity of this mineral, which has been distinguished by the name of *red lead ore of Siberia*, and in 1789 analysed four ounces of it along with Mr Vauquelin. They found it to contain,

Lead	-	-	36 $\frac{3}{8}$
Oxygen	-	-	37 $\frac{5}{8}$
Iron	-	-	24 $\frac{3}{8}$
Alumina	-	-	2
			100 $\frac{5}{8}$

and a little silver*.

Mr Bindheim of Moscow analysed it soon after, and found it to contain,

Lead	-	-	60
Molybdic acid	-	-	11,66
Nickel	-	-	5,66
Oxide of iron	-	-	1
Air and water	-	-	5
Silica	-	-	4,5
			87,82

and a little copper and cobalt †.

Vauquelin examined it again in 1797, and found that all the former analyses were inaccurate.

A hundred parts of this mineral, reduced to a fine powder, were mixed with 300 parts of the saturated carbonat of potafs, and about 4000 parts of water; and this mixture was exposed for an hour to a boiling heat. He observed, 1st, that when these matters began to act upon each other there was produced a strong effervescence, which continued a long time; 2d, that the orange colour of the lead became a brick red; 3d, that at a certain period the whole matter seemed to dissolve; 4th, that in proportion as the effervescence advanced the matter reappeared under the form of a granulated powder of a dirty yellow colour; 5th, that the liquor assumed a beautiful golden yellow colour. When the effervescence had entirely subsided, and appeared to have no longer any action on the substances, the liquor was filtered, and the metallic dust collected on the paper. After being washed and dried, it weighed no more than 78 parts: the potafs, therefore, had taken from it 22 parts.

He poured upon the 78 parts just mentioned some of the nitric acid, diluted in 12 parts of water, which produced a brisk effervescence. The greater part of the matter was dissolved: the liquor assumed no colour, and there remained only a small quantity of powder of an orange-yellow colour. The liquor of the residuum was separated by the help of a syphon, the matter washed several times, and the washings united with the first liquor. This residuum, dried, weighed no more than 14 parts: from which it follows, that the nitric acid had dissolved 64.

He again mixed these 14 parts with 42 parts of the carbonat of potafs and the necessary quantity of water, and

* Ann de Chim. i. 301.

† Berl. Beob. iv. 2911.

556
Analysis of the red lead of Siberia,

Chromic Acid. and then treated them as before, and the phenomena were the same. The liquor, after being filtered, was united to the former; and the residuum, washed and dried, weighed no more than two parts, which were still red lead, and therefore thrown away.

Chromic Acid.

The two nitric solutions, united and evaporated, produced 92 parts of nitrat of lead, crystallized in octahedra, perfectly white and transparent. These 92 parts of nitrat of lead, dissolved in water, were precipitated by a solution of the sulphat of soda. This produced 81 parts of the sulphat of lead, which were equivalent to 56,68 of metallic lead.

557
And discovery of chromic acid.

The alkaline liquors were found to contain a salt composed of potash combined with a peculiar acid, which Mr Vauquelin afterwards called *chromic acid*.

These liquors, subjected to evaporation until a saline pellicle was formed on their surface, produced, on cooling, yellow crystals; among which there was a carbonat of potash, not decomposed. These crystals, dissolved in water, and the solution united with the mother-water, the whole was mixed with weak nitric acid until the carbonat of potash was saturated. The liquor then had a very dark orange-red colour. Being united with a solution of the muriat of tin, newly made, it first assumed a brown colour, which afterwards became greenish. Mixed with a solution of the nitrat of lead, it immediately produced the red lead. Lastly, evaporated spontaneously, it produced ruby-red crystals, mixed with crystals of the nitrat of potash. Ninety-eight parts of this mineral, decomposed as above-mentioned, having produced 81 parts of the sulphat of lead, 100 parts would have given 82,65, which are equivalent to 57,1 of metallic lead. "But admitting, as experiment proves (says Mr Vauquelin), that 100 parts of lead absorb, in combining with acids, 12 parts of oxygen, the 57,1 of metallic lead ought to contain in the red lead 6,86 of this principle, and we ought to have for the mineralizing acid 36,4.

558
Its properties.

Chromic acid crystallizes in the form of elongated prisms of a ruby colour.

When mixed with filings of tin and the muriatic acid, it becomes at first yellowish brown, and afterwards assumes a beautiful green colour.

When mixed with a little alcohol and nitric acid, it immediately assumes a bluish green colour, which preserves the same shade even after desiccation. Ether alone gives it the same colour.

With a solution of nitrat of mercury, it gives a precipitate of a dark cinnabar colour.

With a solution of nitrat of silver, it gives a precipitate, which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by exposure to the light. This combination, exposed to the heat of the blow-pipe, melts before the charcoal is inflamed. It assumes a blackish and metallic appearance. If it be then pulverised, the powder is still purple; but after the blue flame of the lamp is brought in contact with this matter, it assumes a green colour, and the silver appears in globules disseminated throughout its substance.

With nitrat of copper, it gives a chestnut red precipitate.

With the solutions of sulphat of zinc, muriat of bismuth, muriat of antimony, nitrat of nickel, and muriat of platinum, it produces yellowish precipitates when

these solutions do not contain excess of acid. With muriat of gold, it produces a greenish precipitate.

When melted with borax or glass, it communicates to them a beautiful emerald green colour.

Paper impregnated with chromic acid assumes in the light a greenish colour.

When mixed with muriatic acid, the mixture was capable of dissolving gold like aqua regia; when this mixture of the two acids is distilled, oxy-muriatic acid is disengaged, and the liquor assumes a very beautiful green colour.

Sulphuric acid, while cold, produces no effect upon it; but when warmed, it makes it assume a bluish green colour, probably by favouring the disengagement of oxygen.

When this acid is heated along with charcoal, it is reduced to the metal called *chromum*. It is therefore composed of this metal and oxygen. From Vauquelin's experiments, it appears to contain one part of chromum and two parts of oxygen.

Such are the properties of this acid, as far as they have hitherto been discovered. Vauquelin is the only chemist who has examined it; and from his memoir the above account has been taken*.

* Ann. de Chim. xxxv. 114. and Philosophical Magazine, i. 279. and 361.

The four last described acids are called *metallic acids*, because they are composed of metals and oxygen.

It is believed that most of the metals, we would rather say of the metallic oxides, are capable of being converted into acids by being combined with oxygen. It is certain that this is the case with platinum; and

Hermstadt, by distilling nitric acid off tin, converted it into a white mass, soluble in three parts of water, which has been called *stannic acid*†. Several more of the metallic oxides act the part of acids: But no complete set of experiments on this important subject has yet appeared.

† Ann. de Chim. iv. 162.

CHAP. VI. Of AFFINITY.

THE meaning of the word *affinity* has been already explained; and it must appear evident, from the use which has been made of it in this article, that the consideration of the nature of affinity is the most important part of chemistry. While its laws are unknown, chemistry is not a science, but a wilderness of facts without beauty or regularity: every thing is equally perplexing and incomprehensible. The chemist, instead of being able to trace the operations of Nature, is lost in an endless maze of uncertainty, without a guide to conduct him, or a ray of light to illuminate his steps. It is the knowledge of affinity which dispels the darkness, removes the confusion, shews us the order which subsists in all the phenomena of nature, points out their dependence on one another, and enables us to direct them as we think proper, to make them subservient to the improvement of the arts, and thus to render them the ministers of our comforts and enjoyments.

560
Importance of affinity.

1. When two bodies are united together by affinity, how small a portion soever of the compound we examine, we shall always find it to contain both of the ingredients. From this it is evident, that affinity combines bodies, particle with particle.

561
It unites bodies, particle to particle.

By *particles* we do not mean what philosophers have called *atoms*, or the smallest parts into which it is possible to divide matter; but the smallest parts which make

Affinity.

make an integrant of any substance. Water, for instance, consists of oxygen and hydrogen; but when we speak of a particle of water, we do not mean the oxygen or the hydrogen separately, but the smallest possible quantity of these combined in such a manner as to form water. It is the *integrant particles* of bodies which are united by affinity. Thus sulphuric acid is composed of sulphur and oxygen combined together; and ammonia, of hydrogen and azot combined in the same manner. Now when sulphuric acid and ammonia combine, it is not their elements, sulphur, oxygen, azot, and hydrogen, which unite together, particle with particle, but the particles of the acid and the alkali as integrants. This is evident; because if these substances be separated from each other by means of a stronger affinity, they are found precisely in the same state as before they entered into combination.—When the substances which combine are *simple*, the ultimate and integrant particles are the same. But we are not certain that any of the bodies with which we are acquainted is simple, in the strict and proper sense of the word.

562
Opinions of the older chemists about affinity.

2. What is this *affinity* which unites bodies together? The older chemists thought that all solvents, or substances capable of dissolving others, were composed of particles which had the form of wedges or hooks; that solution consisted in the insinuation of these wedges or hooks between the particles of the bodies to be dissolved; and that chemical combination was merely the linking of the different particles together by means of holes in one set of particles, into which the hooks or the wedges of the other set were thrust. Such explanations, absurd as they may appear, were fashionable among chemical philosophers till the days of Sir Isaac Newton, who first ascribed the chemical union of bodies to an *attraction* between the particles themselves. This explanation, after a violent struggle on the part of the chemists, has been at last unanimously adopted.

563
It is an attraction between the particles of bodies.

Affinity, then, is an *attraction* between the particles of different bodies, by which they are *drawn* towards one another, and kept united. This we take for granted, and consider as a *fact*, without pretending to explain *how* they come to be possessed of this power, or *how* they exert it; both of which are evidently beyond the reach of the human understanding.

564
Whether the same with gravitation.

But though we cannot discover the manner in which affinity acts, we can see, at least, that it follows certain laws, and that they are invariable; for similar phenomena always occur when the circumstances are the same. Now what are the laws which affinity follows? There is a species of attraction which matter possesses, called *gravitation*, the laws of which were investigated by Sir Isaac Newton. Is affinity the *same* with gravitation, or does it follow different laws?

Upon a slight view of these two attractions, their phenomena appear very different. Gravitation acts at very great distances; affinity not until the bodies are mixed together: Gravitation acts on the whole mass; affinity only on the particles: Bodies gravitate to one another directly as their masses, and inversely as the squares of their distances. But how can affinity follow these laws, when it does not act till the bodies are ap-

parently in contact? or supposing that it does act, how can they account for the phenomena of affinity? If barytes be presented to a compound of sulphuric acid and potash, the acid immediately leaves the alkali and combines with the earth: But had gravitation been the only power acting, ought not the barytes to have united with the sulphat of potash without producing any decomposition?

Affinity.

These striking differences have convinced many philosophers, as they seem to have done Newton himself, that gravitation and affinity are different species of attraction. Let us not, however, embrace this conclusion vaguely, or without affixing a precise meaning to our words.

Gravitation and chemical affinity are said to be different species of attraction. But what is attraction? It is merely a general *fact*, or that tendency which is *observed* among all the portions of matter towards each other, but which exhibits very different appearances under different circumstances. The tendency of matter towards matter at *sensible* distances is called *gravitation*, and its laws have been completely investigated; but neither that tendency, nor these laws, have been, or can be, shewn to be *essential* to the existence of matter. Chemical affinity is the tendency of particles towards each other at *insensible* distances, or when these particles are mixed together; and this tendency appears to be regulated by laws different from those of gravitation. Like gravitation, it is merely an *observed fact*; and however different these facts may appear to be, they are probably both brought about by the same forces. It is indeed true, that gravitation is directly as the masses of matter, and inversely as the squares of the distances of these masses; while the attraction, which is called *chemical affinity*, seems to observe very different rules. But we have shewn elsewhere (see OPTICS, n^o 62—68, *Encycl.*; and BOSCOVICH in this *Suppl.*), that the same forces repel at one distance and attract at another; and that they may produce all the various phenomena of chemical affinity.

565
No positive proof that it is different.

The difficulties to be accounted for in chemical affinities are their intensity, their different degrees of strength, and their being elective, or, which is the same thing, the capacity which one body has of displacing another.

How come affinities, it may be asked, to differ in intensity? Perhaps we might with propriety refer this querist to the itudy of Boscovich's curve; but as our modern chemists are not generally versant in such studies, we beg leave to observe, in this place, that we have no proof whatever of absolute contact between bodies. On the contrary, it is highly probable, we had almost said demonstrable, that particles are in every instance at some distance from one another. For, on the supposition that two bodies were in actual contact, their attraction for each other would not only be as great as possible, but as great as the attraction of any other body for either of them *could possibly* be: Consequently, it necessarily follows, that, since bodies chemically combined *can* be separated, they are not in actual contact (A); but if they are not in contact, their distance from one another

(A) Perhaps the following demonstration, which we borrow from the ingenious Mr Broughman, will render this more evident. In fig. 7. let the body A have for P an attraction which at the distance of AP is proportional

Affinity. another *may* vary in different cases, and the force of affinity will vary with the distance. Here then is a reason why the affinity of different bodies varies in strength. Sulphuric acid, for instance, has a stronger affinity for barytes than for lime; because when the combinations are formed, the distance between the acid and barytes is not so great as that between the acid and lime.

But why do the distances differ? If affinity be the same with gravitation, it must tend to bring the particles nearer one another: And what then prevents the lime from approaching as near the acid as the barytes does? We reply, *the figure of its particles*. This answer was first given to the question by Buffon, and it is fully adequate to solve the difficulty. The particles of bodies, indeed, are a great deal too minute for us to discover their figure by actual inspection; but the phenomena of crystallization shew us that this difference actually exists.

The crystals of every body assume a peculiar figure. Now as these crystals are all formed in the same manner, and by the same law, it is impossible to conceive any other reason for their variety but the difference in the form of the particles which compose them.

But why does one body displace another? When a particle of barytes is brought within a certain distance of a particle of sulphuric acid and lime combined together, affinity acts and draws them nearer to one another; and the barytes, from its figure, approaches nearer the acid than the lime could, and forms with it a compound, the figure of which is such, relatively to that of the lime, that they cannot approach within a small enough distance of each other to counteract the attraction of the earth. Accordingly no compound is formed; for all that is meant by two particles having formed a compound, is, that their attraction for each other is greater than the attraction of the surrounding bodies for either.

⁵⁶⁶
Conse-
quently it
ought to be
considered
as the same.

Having thus seen that none of the phenomena of *affinity* are inconsistent with their resulting from the forces which bring about the phenomena of gravitation, we have a right to conclude, that it is at least highly probable, that all the motions of the corporeal world are produced by the same power which, though not essential to matter, was impressed upon every atom of it by the Great Creator when he formed this universe; and that as the effects of this power are modified according to the situation of the bodies on which it acts, they are known by the different names of *gravity*, *adhesion*, *cohesion*, and *affinity*.

GRAVITY is the attraction between bodies so distant, that the masses alone influence the result, and that the

power may be considered as placed in the centre of the attracting bodies.

ADHESION supposes a distance too small for our senses. It has been demonstrated to be proportional to the number of touching points, which depends upon the figure of the particles that form the bodies.

COHESION takes place only between particles of the same nature. These, instead of touching only in one superficies, as in adhesion, touch in every point where their figure will allow contact: consequently the force of cohesion also must depend upon the figure of the particles.

AFFINITY unites bodies of a different nature, not merely by one superficies, as *adhesion* does, but particle to particle, like *cohesion*; and the most perfect contact is formed that the figure of the particles will admit. Therefore, in this case also, the intensity depends upon the figure of the particles.

⁵⁶⁷
Saturation
explained.

3. If we make the attempt, we shall find that water will not dissolve any quantity of common salt that we please. Water which refuses to take up any more is said to be *saturated* with salt. Neither can we combine any quantity of potash with a given portion of sulphuric acid: we may add as much of it as we please, indeed; but if we evaporate the liquid, in order to obtain the salt in crystals, we shall find that only *part* of the potash has united with the acid, and that the rest has crystallized separately. From these examples, it must appear evident, that bodies combine with one another by affinity only in certain proportions; or, which is the same thing, that a determinate number of particles of each of the ingredients goes to the formation of an integrant particle of the compound, and that into this integrant *no additional particles* of either ingredient can be admitted. Let us suppose, for instance, that the particles of sulphuric acid are tetrahedrons, and that the particles of potash are of such a form, that one of them can attach itself to each of the sides of the acid particle: In that case an integrant particle of sulphat of potash would be composed of five particles, one of acid and four of alkali; for it is evident, that just four particles of potash would combine with every particle of acid, and that the acid would then be saturated, or, which is the same thing, would be incapable of receiving any more alkaline particles into combination with it. Let us suppose now, that there is just as much potash as saturates the acid; if more acid be poured in, it cannot enter into combination with the potash, because all the potash is already combined with acid.

Thus it appears evident, from the nature of affinity, that the ingredients in every combination must mutually *saturate* each other, and that no more of either can be

tional to PM; then let P move towards A, so as to come to the situation P', and let the attraction here be P'M'; as it is continual during the motion of P to P', MM' is a curve line. Now in the case of the attraction of bodies for one another, PM is less than P'M'; and consequently MM' does not ever return into itself, and therefore it must go *ad infinitum*, having its arc between AB and AC, to which it approaches as asymptotes, the abscissa always representing the distance, and the ordinate the attraction at that distance. Let P' now continue its motion to P'', and M' will move M''; and if P'' meets A, or the bodies come into perfect contact, P''M'' will be infinite; so that the attraction being changed into cohesion will be infinite, and the bodies inseparable, contrary to universal experience; so that P can never come nearer to A than a given distance. *Nicholson's Journal*, I. 555.

Affinity.

be admitted into the compound than what is necessary to produce this saturation. It follows equally, that there can be *no union* without saturation, except there be a deficiency in some one of the ingredients: For supposing that there is a sufficient number of particles of potash, and that every particle of sulphuric acid requires four of them, as before, for saturation, the very same cause that produces the union of one, two, or three particles of potash with a particle of acid, must produce the union of all the four.

Even when there is a deficiency of one of the ingredients, saturation must equally take place; for those particles of acid that happen to be nearest the alkali must still be saturated; because the affinity of all the acid particles for alkali was originally equal, and the difference of the distance must give the superiority to those that are nearest; and those particles of acid that are once saturated with potash cannot be deprived of it by any of the other particles, otherwise the affinity of some particles of sulphuric acid for potash would be greater than that of others; which is absurd.

It will no doubt be objected to all this, that there are innumerable instances of additional portions of some one of the ingredients being received into a compound after saturation, and that some substances seem to be equally well saturated with different doses of another. Oxygen, for instance, combines with azot in three different proportions, and forms nitrous gas, nitrous acid, and nitric acid. The metals, too, form, in the same manner, different oxides; and a great many instances of the same kind occur among the neutral salts.

But it ought to be remembered, that the conclusions against which these objections are urged, are consequences deduced, we think fairly, from a proposition which we consider as demonstrated, that *affinity is a species of attraction* (v). These phenomena cannot therefore be admitted as valid objections, except it can be shewn that they are really *incompatible* with these conclusions. Now that this is not the case, has been shewn, in the most satisfactory manner, by Morveau*. These apparent exceptions are owing to an affinity which exists between the compound as an integrant and one of its ingredients, and are not instances of various degrees of saturation, but of the formation of new compounds. According to this very ingenious idea, which, we believe, first originated with Bergman, and was first seen in its full extent by Morveau, we have formerly explained in what manner the various metallic oxides are formed: the first oxide is a compound of the metal and oxygen; the second, of the first oxide and oxygen; the third, of the second oxide and oxygen; and so on. In the same manner we have explained the various combinations of azot and oxygen: and the explanation may easily be extended to every other case. These apparent objections, then, are not incompatible with the above con-

clusions, but perfectly consistent with them; and consequently they cannot be admitted as of any force.

There is one phenomenon, indeed, which proves, independent of these conclusions, that these combinations are actually formed in the manner we have supposed, and which therefore merits particular attention. The phenomena is, that the affinity between the two simple substances is *almost always greater* than that between the compound and any of its ingredients. The affinity, for instance, between azot and oxygen is greater than that between nitrous gas and oxygen; and the affinity between nitrous gas and oxygen greater than that between nitrous acid and oxygen: For if nitrous gas be mixed with nitric acid, the whole is converted into nitrous acid; but no change whatever is produced when nitric and nitrous acids, or nitrous gas and nitrous acid, are mixed: and every substance which is capable of decomposing nitrous gas is capable also of decomposing nitrous and nitric acids; but many substances are capable of decomposing nitrous and nitric acids which have no effect upon nitrous gas. In the same manner, the affinity between sulphur and oxygen is greater than that between sulphurous acid and oxygen: for when sulphur is mixed with sulphuric acid, the whole is converted into sulphurous acid; but no change takes place when sulphur and sulphurous acid, or sulphurous and sulphuric acids are mixed together. A great many instances of the same kind might easily be produced, if these were not sufficient to establish the point. This curious fact affords a very strong proof that the bases, as well as the quantity of oxygen, is different in almost all the vegetable acids. Did the tartarous, oxalic, and acetous acids, for instance, consist of the same base with various doses of oxygen; were the tartarous composed of the base and oxygen; the oxalic, of tartarous acid and oxygen; the acetous, of oxalic acid and oxygen in that case, a mixture of acetous and tartarous acids ought to form oxalic acid: but that this does not happen, any one may convince himself by actual experiment.

We do not mean to affirm that this fact, though it is certainly very often true, holds in all cases; in some, perhaps, the reverse may be true, though we do not recollect at present any instance of that kind.

4. Since the affinity of almost every two bodies for ⁵⁶⁸ each other differs in *strength* from that between every ^{of the} other two, it becomes an important problem ^{of affinity.} to determine the strength of every affinity in numbers. The solution of this problem would give a clearness and precision to chemistry equal to that of any other branch of natural philosophy whatever, and enable it to advance with a degree of rapidity hitherto thought unattainable. No wonder, then, that this problem has occupied the attention of some of the most eminent philosophers who have dedicated their time to chemistry.

If the observations formerly made, in order to shew ⁵⁶⁹ Attempts that to ascertain it.

(v) Were any farther proof of this proposition required, we would observe, that *cohesion* acts as an antagonist to affinity, and may be often rendered so strong as to prevent affinity from acting with efficacy. Thus alumina and jargonina, when sufficiently heated, become insoluble in acids, without undergoing any other alteration than that of an increase of cohesion by their particles being brought nearer each other; for destroy this cohesion, and they become as soluble as ever. Now it follows from this, that if cohesion be *attraction*, so must *affinity*. The experiments of Morveau, to be afterwards mentioned, demonstrate, that *adhesion* and *affinity* are produced by the same cause: Consequently, if adhesion be attraction, so must affinity.

* Encyc.
Method.
t. 560.

Affinity. that the difference in the strength of affinities depends upon the different forms of the particles which have an affinity for each other, be conclusive, it is evident that the certain method of learning the strength of affinities would be to discover the forms of the particles of all bodies. But no method has hitherto been discovered by which it is possible of becoming acquainted with the figure of the particles of bodies. The experiments indeed of the Abbé Hauy (afterwards to be described) point out a method by which the primary figure of crystals may be investigated with a good deal of plausibility; but this leaves the knowledge of the figure of the particles which compose these crystals still uncertain.

As nobody, therefore, has attempted to take this road, in order to calculate the strength of affinities, let us at present consider the different methods which have been proposed for that purpose, that we may see whether any of them will answer the end intended.

⁵⁷⁰
By Wenzel, Wenzel supposed that the time taken by one body to dissolve another is a measure of the affinity which subsists between them. But the hypothesis of that ingenious philosopher will not bear the test of examination; for the *time* of solution evidently depends upon circumstances unconnected with affinity. The cohesion of the body to be dissolved, and the nature of the compound formed, must occasion very great differences in the time of solution of different bodies, even on the supposition that their affinities were all the same.

⁵⁷¹
Fourcroy, Fourcroy proposed to measure the affinity of bodies by the difficulty of separating them after they are combined: but we have no method for measuring this difficulty. Lavoisier and De la Place, indeed, proposed *caloric* for this purpose; but there are many compounds which caloric cannot separate; and it never produces a separation except by means of its affinity for one or other of the ingredients of the compound. Before caloric, therefore, could be employed as a measure, it would be necessary to know exactly the strength of its own affinity for every other substance; which is just a case of the problem to be resolved.

⁵⁷²
Macquer, Macquer supposed that the affinity of bodies for one another was in the compound ratio of the facility of their union and the difficulty of their separation: But as we are in possession of no method of ascertaining either of these, it is evident that this theory, even allowing it to be just (which it certainly is not), could be of no use for assisting us to calculate the force of affinities.

⁵⁷³
Morveau, Another method has been proposed by the distinguished philosophical chemist Mr de Morveau (c).

In 1713 Dr Brook Taylor made some experiments on the adhesion of surfaces; and concluded from them, that the force of adhesion might be determined by the weight necessary to produce a separation. But in 1772, Messrs La Grange and Cigna, observing that the surfaces of water and oil adhere together, and taking it for granted that these two liquids *repel* each other, concluded, in consequence, that their adhesion was not owing to *attraction*; and hence inferred, that *adhesion*, in general, is always owing to the pressure of the at-

mosphere. This conclusion induced Morveau to examine the subject: he found that adhesion was *not affected* by the pressure of the atmosphere; for it required the same weight to separate a disk of glass (30 lines in diameter) from the surface of mercury in the open air, and under an exhausted receiver. He observed that the same disk adhered to water with a force of 258 grains, and to the solution of potash, though denser, only with a force of 210. This result not only proved that adhesion was owing to attraction, but made him conceive the possibility of applying this method to the calculation of affinities: For the force of adhesion being necessarily proportional to the points of contact, and this being the case also with affinity, it is evident that the adhesion and the affinity between the same substances are proportional, and that therefore the knowledge of the one would furnish us with the ratio of the other.

Struck with this idea, he constructed cylinders of different metals, perfectly round, an inch in diameter and the same in thickness, and having a small ring in their upper surface, by which they might be hung exactly in equilibrium. He suspended these cylinders, one after another, to the beam of a balance; and after counterpoising them exactly, applied them to a quantity of mercury placed about two lines below them, making them slide along its surface, to prevent any air from lodging between them and the mercury. He then marked exactly the weight necessary to overcome their adhesion, taking care to change the mercury after every experiment. The table of the results is as follows:

Gold adheres to mercury with a force of	446 gr.	
Silver, - - - - -	429	
Tin, - - - - -	418	
Lead, - - - - -	397	
Bismuth, - - - - -	372	
Platinum, - - - - -	282 *	* Morveau,
Zinc, - - - - -	204	Ann de
Copper, - - - - -	142	Chim. xxv.
Antimony, - - - - -	126	10.
Iron, - - - - -	115	
Cobalt, - - - - -	8	

The differences of these results cannot be owing to the pressure of the air, which was the same in all; nor do they correspond to the densities of the metals; nor can they be owing to accidental differences in the polish of the cylinders, for a plate of rough iron adheres more strongly to mercury than one of the same diameter exquisitely polished;—but they follow precisely the order of affinity, and therefore may be considered as the measure of the strength of the affinity between these different metals and mercury. They furnish us also with a convincing proof that *affinity is attraction*, and the same species of attraction with *adhesion*; and that therefore, if the one be reducible to *gravitation*, so must the other.

Mr Achard, convinced of the importance of Mr Morveau's observations, made a great many experiments on *adhesion*, and published the result of them in 1780. He proved

X x

proved

(c) Now Mr Guyton: we have used the old name all along in the text to avoid ambiguity.

Affinity. proved that the force of adhesion was not affected by alterations in the height of the barometer, but that its force became weaker as the heat of the fluid increased (D); and that the temperature remaining the same, the force of adhesion increased in the same ratio with the surfaces of the adhering bodies. He made about 600 experiments on the adhesion of different solids and fluids, proved that the force of adhesion did not depend on the densities of the adhering bodies, nor on the different cohesive force of the fluids; and, after a laborious calculation, concluded that it depended on the figure of the particles of the adhering fluid and solid.

These experiments and calculations of Mr Achard are certainly of importance; and we would have given them here, had not the objects of them been substances which can furnish but few data for calculating the force of affinities.

This method of measuring the force of affinities seems to be an accurate one, and if it could be applied to every case of affinity, would, in all probability, enable us to solve the problem which we are now considering: But, unfortunately, its application is very limited, being confined to those cases alone in which one of the bodies can be presented in a fluid, and the other in a solid state. Nor can it be applied indiscriminately to all those cases; for whenever the cohesion of any liquid is much inferior to the force of its adhesion to any solid, the separation takes place in the particles of the liquid itself, and consequently we do not obtain the measure of its adhesion to the solid, but of its own cohesion, and that, too, imperfectly. Thus, for instance, Mr Achard found that sealing-wax adhered to water with a force of 92 grains, and to alcohol only with a force of $53\frac{1}{3}$ ths; yet we know that sealing-wax has a greater affinity for alcohol than for water; because alcohol dissolves it, which water is incapable of doing. The difference in the result in this instance was evidently owing to the smaller cohesion of alcohol. Mr Morveau's method must therefore be confined to those cases in which the cohesion of the liquid is stronger than its adhesion to the solid, which may be known by the surface of the solid not being moistened; and to those in which the cohesion is not much inferior to the adhesion; for then, it is evident, that the force of cohesion will be increased as the force of adhesion. Let us suppose, for instance, that two solids, A and B, are made to adhere to the surface of a liquid, and that A can only form an adhesion with 50 particles of the liquid, whilst B adheres to 100; it is evident that a much smaller force will destroy the cohesion of the 50 particles to which A adheres with the rest of the liquid, than what will be required to destroy the cohesion of the 100 particles united to B with the same liquid*.

* Morveau, *Encyc. Method. Chim. art. Adhesion.*

The method of Mr Morveau, then, may be applied with accuracy in both cases; and when they occur can only be determined by experiment. It cannot, however, be applied indiscriminately even then; for unless the solid and the fluid be presented in such a state that

no gas is extricated when the adhesion takes place, an accurate judgment cannot be formed of the force of adhesion. When marble (carbonat of lime), for instance, is applied to the surface of sulphuric acid, there is an extrication of gas, which very soon destroys the adhesion, and prevents an accurate result. Were it possible to employ quicklime instead of marble, this would be prevented; or if this cannot be accomplished, why might not lime be employed, united with some acid that would not assume a gaseous form, and at the same time has a weaker affinity than sulphuric acid for lime? Why might not the phosphat of lime, for instance, be used, which may be reduced to a state of hardness sufficiently great for the purpose? The extrication of gas, during the application of metals to the surfaces of acids, might be prevented by oxidating their surfaces. It is true, indeed, this could not be done with all the metals, on account of the nature of the oxide, but it might with several; copper, for instance, and silver. It cannot be doubted, that by these methods, and other contrivances that might be fallen upon, a sufficient number of results might be obtained to render this method of the greatest importance. It is rather surprising, therefore, that it has never been prosecuted.

Mr Kirwan has proposed another method of solving ⁵⁷⁴ the problem. While he was engaged in his experiments ^{And Kirwan.}

on the strength of acids, he observed that the quantity of real acid necessary to saturate a given quantity of each of the bases, was inversely as the affinity between the respective bases and the acid; and that the quantity of each of the bases necessary to saturate a given quantity of acid was directly as the affinity between the base and the acid. Thus 100 grains of each of the acids require more alkali for saturation than lime, and more lime than magnesia, as may be seen in the following table:

100 grains of	Potafs.	Soda.	Lime.	Amm.	Mag.	Alum.
Sulphuric acid	215	165	110	90	80	75
Nitric acid	215	165	96	87	75	65
Muriatic acid,	215	158	89	79	71	55

He concluded, therefore, that the affinity between acids and their bases may be estimated by the quantity of bases necessary for saturation. Thus the affinity between potafs and sulphuric acid is 215, and that between nitric acid and lime 96*.

* We have mentioned formerly, that the principle on which Mr Kirwan calculated the strength of the acids was founded on a mistake. It must follow of course, therefore, that the numbers which result from it must also be wrong. This Mr Kirwan has acknowledged, and seems to have given up all thoughts of ascertaining the strength of affinities by this method. But before it be abandoned altogether we wish the following observations were considered.

Bergman long ago established as a principle, under ⁵⁷⁵ the name of a chemical paradox, that *the stronger any salt was, the less of any other it required for saturation.* ^{Attempt to remedy the defects of his method;} Thus, according to him,

100

(D) Strictly speaking, this is owing not so much to a decrease of the force of adhesion, as of that of the cohesion of the fluid itself.

Affinity.

100 parts of potafs require	78,5 Sulphuric acid,
	64 Nitric,
	51,5 Muriatic,
	42 Carbonic,
100 parts of foda - -	177 Sulphuric,
	135,5 Nitric,
	125 Muriatic,
	80 Carbonic.

ted by Morveau *, evidently resolves itself into the two following :

1. A base requires the more of an acid for saturation the stronger its affinity for that acid is.
2. An acid requires the more of any base for saturation the greater affinity it has for that base.

In order to judge of the truth of the first of these propositions, let us examine the following table, drawn up from the experiments of Bergman, Wenzel, and Kirwan.

Affinity.
* Encyc.
Method.
Cbim. i. 597.

100 parts of	BERGMAN.			WENZEL.			KIRWAN.		
	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.	Sulphuric.	Nitric.	Muriatic.
Barytes	15,4		30,8						
Potafs	78,6	64	51,5	82,4	107,7	54	81,8	87,1	78,2
Soda	175	135,5	125	125,8	166,6	83	129,4	136,1	114,2
Lime	143,7	134,4	70,45	147,74	195,6	103,6	141	180	86
Magnesia	173,67	159,25	82,92	181,8	257,15	122,27	170,5	255	104,275
Ammonia				142,42	201,22	96,25	187,5	233	116
Alumina	211,11		220,2	77,7	68,7	38,6			

It is evident at first sight, that Bergman's experiments correspond exactly with the proposition. To saturate, according to him, 100 parts of potafs, requires 78,6 of sulphuric acid, 64 of nitric, and 51,5 of muriatic acid. There is only one deviation from the proposition in the whole table, and this regards barytes, which, according to him, is saturated with 15,4 of sulphuric and 30,8 of muriatic acid. But Mr Morveau has shewn, by several accurate experiments, that barytes requires much more sulphuric acid for saturation than Bergman supposed *. And Klaproth has shewn, that 100 parts of barytes require 49,2 of strong sulphuric acid for saturation †. And Dr Withering's calculation ‡ agrees almost exactly with this; nor does that of Fourcroy differ much from it §. Instead of 15,4 of sulphuric acid, therefore, which, according to Bergman, are necessary to saturate 100 of barytes, it should be 42,8.

The first and last columns of Wenzel and Kirwan's experiments agree equally well with the proposition, but the second deviates from it completely. Wenzel probably might have been misled by the manner of performing his experiments; but the same objection does not seem to lie against those of Kirwan.

It can scarcely be doubted, however, to whatever cause the error is to be imputed, that the numbers in the second column of Mr Kirwan's table are too large. The following experiment of Morveau is sufficient to shew this.

According to Mr Kirwan's experiments, the proportions of acid and alkali in the four following salts are under :

Sulphat of potafs	{ Acid	100
	{ Potafs	108,7

Sulphat of lime	{ Acid	100
	{ Lime	80,6
Nitrat of potafs	{ Acid	100
	{ Potafs	83,33
Nitrat of lime	{ Acid	100
	{ Lime	34,4

Now when sulphat of potafs and nitrat of lime are mixed together, a double decomposition takes place, and sulphat of lime and nitrat of potafs are formed. Let these two salts be mixed together; let the quantity of sulphat of potafs be such, that the acid contained in it amounts to 100; and let a more than sufficient quantity of nitrat of lime be added, to saturate the sulphuric acid with lime. It is evident that for that purpose 80,6 of lime must be present; and the quantity of nitric acid combined with these 80,6 must be 234,4. This quantity would require for saturation 195,32 of potafs, but there are only 108,7 in the mixture; consequently there ought to exist in the mixture, after the mutual decomposition of the salts, 64,87 of nitric acid in a state of liberty. Such would be the result, provided Mr Kirwan's numbers were accurate; but the fact is, that no such excess of acid exists in the mixture †; and consequently the quantity of nitric acid contained in nitrat of lime is stated too high by Mr Kirwan. Although therefore Mr Kirwan's tables do not coincide with the proposition which we are considering, this is not to be considered as a proof of its falsehood; as there is reason, from the experiment above described, to suspect some error in the data from which Mr Kirwan calculated the strength of the acids.

The truth of the second proposition may be judged of by the following Tables :

* Encyc. Method. Cbim. i. 591.
† Cbim. Ann. ii. 1785.
‡ Phil. Transf. 1784.
§ Ann. de Cbim. iv. 65.

† Ann. de Cbim. xxv. 295.

Affinity.

According to BERGMAN.

100 parts of	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amn.	Alum.
Sulp. acid	646	127,5	56,5	69,5	578	42	473
Nitric acid		148,4	74,4	74,4	62,8		
Mur. acid	324,7	194	78	141,9	120,5		40

According to WENZEL.

100 parts of	Byryt.	Potafs.	Soda.	Lime.	Magn.	Amn.	Alum.
Sulp. acid		120,8	79,16	67,2	55	70,2	128
Nitric acid		92,7	60	51,1	38,8	49,7	147,8
Mur. acid		183,8	119,2	96,5	81,7	103,9	259

According to KIRWAN.

100 parts of	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amn.	Alum.
Sulp. acid		122,2	77,2	70,4	57,3	53,3	
Nitric acid		112	73,8	55,5	39,2	44,8	
Mur. acid		168,6	133	112,7	89,9	78,5	

It appears that all the table of Bergman agrees with the proposition except the numbers which correspond to sulphat of soda, sulphat of alumina, nitrat of lime, and muriat of soda, which the late experiments of Mr Kirwan have sufficiently shewn to be inaccurate.

Wenzel's table corresponds exactly, except the columns under ammonia and alumina, which Morveau has proved to be inaccurate.

Kirwan's table corresponds exactly, except with regard to the quantity of ammonia necessary to saturate muriatic acid, which does not appear to have been accurately determined by experiment.

Let us therefore take the truth of these two propositions for granted, and let us consider every deviation from them as an error; and let us see whether they will enable us to discover the absolute affinity of sulphuric, nitric, and muriatic acids, for their respective bases.

TABLE I. *Quantity of Base necessary to Saturate 100 Parts of the three Acids.*

100 parts	Baryt.	Potafs.	Soda.	Lime.	Magn.	Amn.
Sulph. acid	233,3	123,3	78,7	68,3	56,8	49,3
Nitric acid	258,4	148,4	95,6	74,4	62,8	54,8
Muriat. acid	324,7	188,8	126,1	116,7	97,3	78,5

TABLE II. *Quantity of Acid necessary to Saturate 100 Parts of the six Bases.* Affinity.

100 parts	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	42,8	38,7	30,8
Potafs	81	64	52,9
Soda	126,7	101,4	79
Lime	145,7	134,4	87,5
Magnesia	176,2	159,25	105,4
Ammonia	202,6	182,4	127,25

The first of these tables represents the affinity between the same acid and its various bases; and the second that of the bases for the different acids. If it were required to know the ratios of the affinity which different bases have for any particular acid, the first table, supposing it accurate, would give it exactly. In like manner, if it were required to know the ratios of the affinity of the acids for the various bases, we would find them in the second table.

But if we wished to know what was the affinity between one acid and base, compared with that between another acid and a different base; or if we wanted to

have not the relative but the absolute affinity between two bodies—it is plain that we could not find it in either of the tables; for the absolute affinity must consist of two things, the affinity which the acid has for the base, and the affinity which the base has for the acid. Now the first table gives us the one of these, and the second the other; so that in order to represent affinity in absolute numbers, the two tables must be multiplied into one another. This was the mistake into which Mr Kirwan fell. His method consisted merely in constructing a table like our first, which (supposing the numbers accurate) gave only the affinity between the bases and the same acid, but left out the affinity between the different acids and the same base; consequently the different columns could not be compared with each other.

It is evident, however, that if the tables were multiplied together in their present state, they could not possibly give an accurate table of affinities. For that purpose, it is necessary to put the same number in the first column of each table, and then to substitute other numbers in the remaining columns, having the same ratio to one another with the numbers in the original columns. This is done in the following Tables:

TABLE I. *Ratios of the Affinity of six Bases for three Acids.*

	Barytes.	Potafs.	Soda.	Lime.	Magn.	Amn.
Sulph. acid	100,00	52,85	33,73	29,27	24,34	21,12
Nitric acid	100,00	57,43	36,98	28,77	24,28	19,59
Mur. acid	100,00	58,11	38,81	35,70	29,94	24,15

Affinity. TABLE II. *Ratios of the Affinity of three Acids for six Bases.*

	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	100,00	90,42	74,54
Potafs	100,00	79,01	65,30
Soda	100,00	80,03	62,35
Lime	100,00	92,24	60,05
Magnesia	100,00	90,34	59,68
Ammonia	100,00	90,02	62,77

TABLE III. *Affinity between three Acids and six Bases in Absolute Numbers.*

	Sulph. acid.	Nitric acid.	Mur. acid.
Barytes	10000	9042	7454
Potafs	5285	4537	3794
Soda	3373	2969	2419
Lime	2927	2653	2143
Magnesia	2434	2193	1786
Ammonia	2112	1763	1515

On the supposition that the two propositions mentioned above were strictly true, and that the numbers which we fixed upon were precisely the quantities of acid and base necessary to saturate each other reciprocally, this last table would represent accurately in numbers the strength of the affinities of the three acids for each of the six bases respectively.

We must acknowledge, however, that the truth of these propositions has not hitherto by any means been sufficiently proved; but a great number of facts concur to render them exceedingly probable, and highly worthy of the attention of chemical philosophers. And we hope that the method proposed by Morveau, and which had been previously practised by Richter, of verifying theoretical calculations of the composition of the salts, by mixing together two salts which mutually decompose each other, and ascertaining whether the result corresponds with calculation, will be followed out, and that it will be the means of ensuring more accuracy than it has hitherto been possible to obtain.

No one will suspect that any thing which has here been said is meant as a reflection on the ingenious chemists who have attempted to solve this most difficult of all chemical problems, the proportion of the ingredients which enter into the composition of the salts. Mr Kirwan, in particular, is entitled to the greatest praise for the persevering industry with which he has prosecuted

the subject, for the candour which he has displayed, and for the new rout which he has opened to the chemical philosopher. Though this problem has not hitherto been solved, and though the difficulties which surround it are almost insurmountable, we may hope much from the general sense which is at present entertained of its importance, and from the zeal and abilities of those philosophers who have particularly turned their attention to it.

In the mean time, the following Table of the strength of affinities by Morveau, though the numbers be arbitrary, will be found of very great use*.

	Sulph. acid.	Nitric acid.	Muriat. acid.	Acetous acid.	Carbonic acid.
Barytes	66	62	36	28	14
Potafs	62	58	32	26	9
Soda	58	50	31	25	8
Lime	54	44	24	19	12
Ammonia	46	38	21	20	4
Magnesia	50	40	22	17	6
Alumina	40	36	18	15	2 (D)

5. Although every chemical combination is produced by the same general law, yet as their phenomena vary somewhat according to circumstances, affinities have, for the sake of greater perspicuity, been divided into classes. These classes may be reduced to *three—simple, compound, and disposing* affinities.

The *first class* comprehends all those cases in which only *two bodies* combine together; as, for instance, sulphuric acid and potafs, oxygen and carbon. The affinities which belong to this class are known by the name of *simple or single affinities*. Although one of the substances to be combined happens to be already united with another body, the combination is still reckoned a case of single affinity. Thus suppose the sulphuric acid previously combined with magnesia, and forming with it the salt called *sulphat of magnesia*, as soon as potafs is presented, the acid leaves the earth (which is precipitated), and unites with the alkali. Even when three bodies combine, it often happens that the union is produced merely by single affinity. Thus, when some potafs is dropped into tartarous acid, part of the acid unites with the alkali, and forms tartrate of potafs; after this the remainder of the acid combines with the tartrate just formed, and composes a new salt known by the name of *acidulous tartrate of potafs*, or *tartar*. This is evidently nothing else than two instances of simple affinity immediately following each other.

When more than three bodies are mixed, decompositions and new combinations often take place, which could

(D) This table, however, does not correspond quite accurately to all the phenomena. For instance, according to it, sulphat of barytes is not decomposed by carbonat of soda, although the contrary takes place in fact.

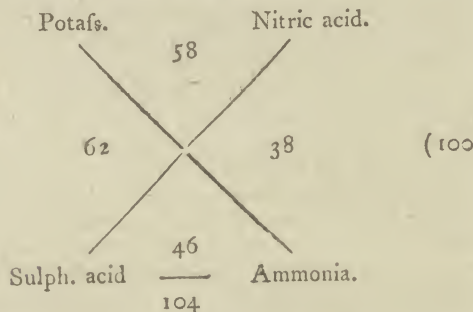
Affinity.

* *Essays*
Method.
Chim. i. 773.
577
Morveau's
table of
affinity.

578
Three
classes of af-
finity,
579
Viz. simple
affinity.

580
Compound
affinity,
could

Affinity. could not have been produced had the bodies been presented in a different state. If, for instance, into a solution of sulphat of potafs there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger affinity for potafs than nitric acid has. For the very same reason, ammonia may be poured into the solution without producing any change. But if nitrat of ammonia be poured in, a decomposition instantly takes place, and two new bodies, *sulphat of ammonia* and *nitrat of potafs*, are formed. Such cases of decomposition form the *second class of affinities*. They were called by Bergman cases of *double elective attraction*; a name which is exceedingly proper when there are only four bodies concerned. But as there are often more than four, it is necessary, as Mr Morveau has observed, to employ some more comprehensive term. We shall therefore call the affinities belonging to this class *compound affinities* (E); and comprehend under the term all cases where more than three bodies are present, and produce combinations which would not have been formed without their united action. In these cases the affinity of all the various bodies for each other acts, and the resulting combination is produced by the action of those affinities which are strongest. The manner in which these combinations and decompositions take place, was first clearly explained by Dr Black. Let the affinity between potafs and sulphuric acid be = 62; that between nitric acid and ammonia = 38; that between the same acid and potafs = 58; and that between the sulphuric acid and ammonia = 46. Now, let us suppose that all these forces are placed so as to draw the ends of two cylinders crossing one another, and fixed in the middle in this manner,



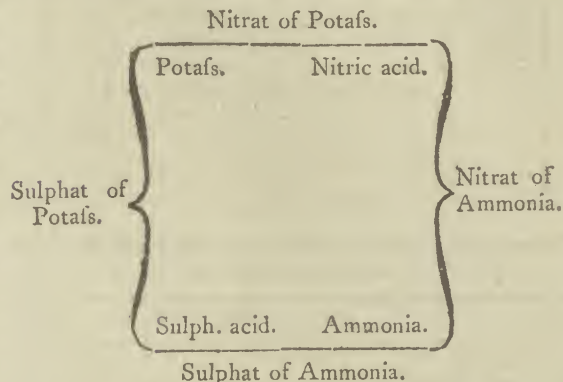
It is evident, that as 58 and 46 = 104, are greater than 62 + 38 = 100, they would overcome the other forces and shut the cylinders. Just so the affinity between potafs and nitric acid, together with that between sulphuric acid and ammonia, overcomes the affinity between potafs and sulphuric acid, and that between nitric acid and ammonia, and produces new combinations.

In all cases of compound affinity, there are two kinds of affinities to be considered; 1st, Those affinities which tend to preserve the old compound, these Mr Kirwan has called *quiescent* affinities; and those which tend to destroy them, which he has called *divellent* affinities.

Thus, in the instance above given, the affinity between potafs and sulphuric acid, and that between nitric acid and ammonia, are quiescent affinities, which endeavour to preserve the old compound; and if they are strongest, it is evident that no new compound can take place. On the contrary, the affinity between potafs and nitric acid, and that between sulphuric acid and

Affinity. ammonia, are divellent affinities; and as they are in this case strongest, they actually destroy the former combinations and form new ones.

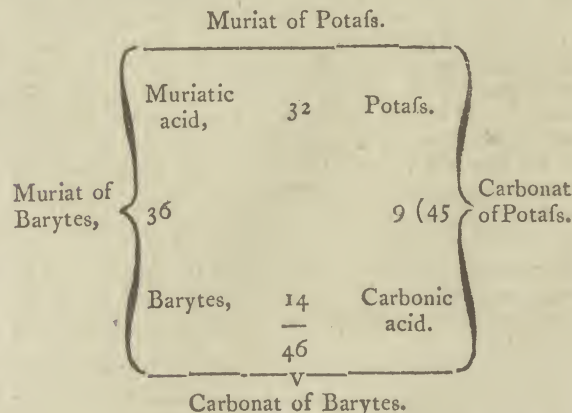
Bergman, who published a great many cases of compound affinities, employed to explain them a method somewhat different from this. He would have represented the above case in the following manner:



At the four corners of an imaginary square are placed the four substances, so that one acid shall be diagonally opposite to another. On the right and left side of the square are placed the old compounds, each on the side of its own ingredients, and above and below are placed the new compounds.

Mr Elliot improved this method of Bergman, by adding numbers expressive of the affinity of the various substances. It is in cases of compound affinity that the ratios of affinities, if we were possessed of them, would be peculiarly useful. For it is evident, that if we knew the strength of affinities in absolute numbers, we would be able to determine before hand all the cases of compound affinity.

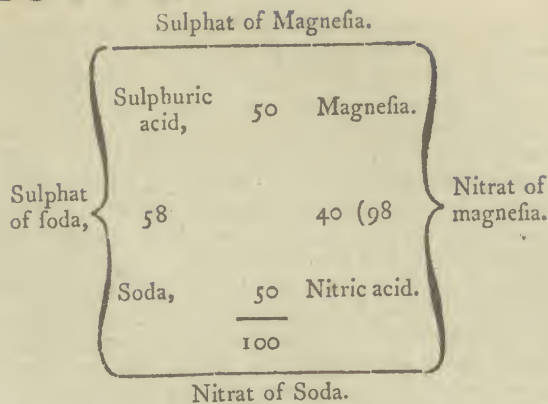
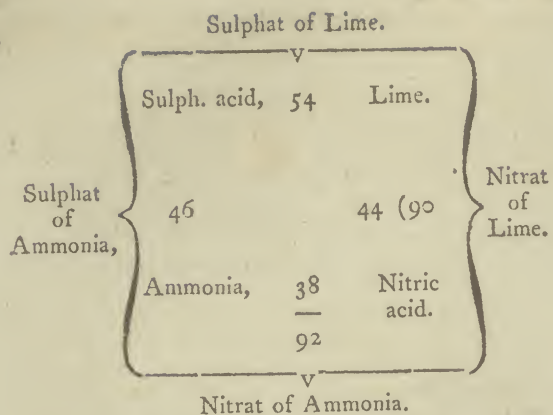
If we knew, for instance, that the affinity between the muriatic acid and barytes were = 36; that between the same acid and potafs = 32; the affinity between potafs and carbonic acid = 9; and that between the same acid and barytes = 14;—we would be certain, previous even to experiment, that when muriat of barytes and carbonat of potafs are mixed, a double decomposition would take place; which we know from experiment to be actually the case.



Another instance of decomposition by compound affinities.

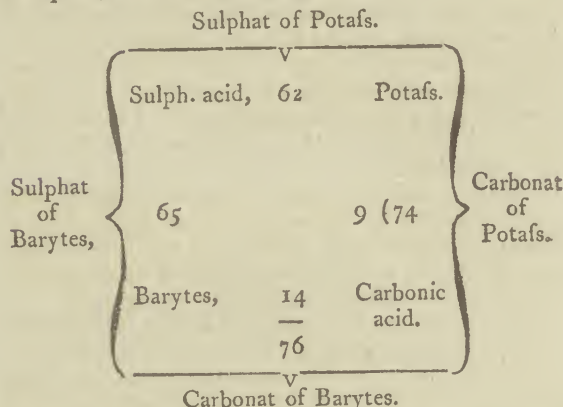
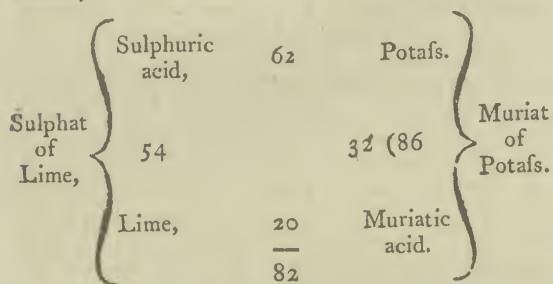
Sulphat

(E) Morveau called them *affinité par concours*.



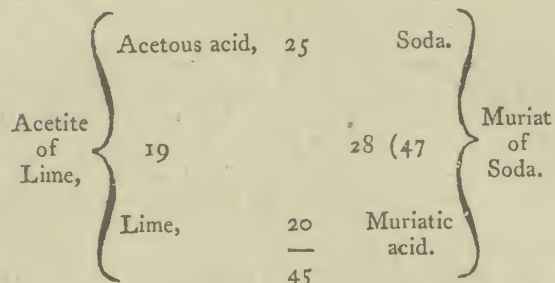
Supposing Morveau's numbers exact, it follows also, even prior to experiment, that no decomposition takes place when sulphat of lime and muriat of potafs are mixed;

When a new compound is precipitated, a line bent downwards in the middle is to be placed between it and the square, as in the following scheme:



for the quiescent affinities are 86, and the divellent only 82.

Nor when acetite of lime and muriat of foda are mixed;



because the quiescent affinities are 47, and the divellent only 45. These cases where no decomposition takes place have been called by Morveau cases of *inverse* compound affinity.

Morveau has proposed the following improvements in representing these cases of compound affinities*.

* *Encyc. Method. Chim. i. 556.* When decomposition does not take place, nothing is to be written above and below the square, as in the two last examples. When a new compound remains dissolved, a straight line is to be placed between it and the square, as in the following scheme.

When a new compound is sublimed, the line between it and the square is to be pointed upwards in the middle, thus

When a new compound is partly dissolved and partly precipitated, the line placed between it and the square is to assume the following shape: _____

When it is partly dissolved and partly sublimed, the following is the line to be used: _____

The third class of affinities has been called by Mr ⁵⁸¹ Morveau *disposing* affinities, because they *dispose* ^{And disposing} substances to combine that would not otherwise have done it. Suppose, for instance, that sulphur is presented to oxygen gas, it does not manifest any affinity for it; but combine it previously with potafs, and it unites with oxygen with avidity. Its previous union with potafs, in this case, *disposed* it to unite with oxygen. The cause of this curious affinity is not yet well understood. If we consider what it was that prevented the sulphur and oxygen from combining, we shall find that it can only be its own attraction of cohesion, and the affinity between the oxygen and caloric which are combined. Whatever then diminishes this attraction of cohesion, or of *aggregation* as it has been called, must facilitate the union of

Affinity. of the sulphur with oxygen. This is done in some measure by the potash. Besides, if affinity depends upon the figure of particles, it is evident that there must be an affinity between the new compound and oxygen; but the moment the oxygen approaches within a certain distance of the sulphur, it unites with it, as its affinity is much greater for that substance than for the compound.

The following is another instance of this curious affinity: Sugar, as Lavoisier has proved, is composed of oxygen, hydrogen, and carbon: Now if concentrated sulphuric acid be poured upon sugar, the oxygen and hydrogen combine, and form water, which unites with the acid, and the carbon is precipitated. In this case, the presence of the acid *disposed* the oxygen and hydrogen to combine. In what manner this new combination is produced, it would not be easy to explain: not by weakening the attraction of cohesion; for we do not see how the acid could produce that effect. The only explanation that can be given, is to suppose that the sulphuric acid, when it approaches within a certain distance of the oxygen and hydrogen, attracts them; and that this attraction, together with the affinity between the oxygen and hydrogen, is greater than that which produces the combination between the ingredients of the sugar themselves: the consequence of which must be decomposition.

582
Why bodies require different temperatures to unite.

6. We come now to one of the most difficult questions in chemistry—Why do bodies require different temperatures in order to unite? and why does the presence of caloric in many cases favour or rather produce union, while it prevents or destroys it in others?

These questions were proposed at the end of the second Chapter of this article; and we reserved them for this place, not because we hoped to be able to answer them in a satisfactory manner, but because no intelligible answer could be given till the nature of affinity had been previously considered. Some substances, phosphorus for instance, combine with oxygen at the common temperature of the atmosphere; others, as carbon, require a higher temperature; and others, as hydrogen and azotic gas, do not combine except at a very high temperature. To what are these differences owing?

In answer to this question, we observe, that the attraction of *cohesion* evidently opposes that of *affinity*. Those bodies which we present to combine together are generally aggregates, or, which is the same thing, consist of many similar particles united by cohesion: for we have no method of separating bodies into their integrant particles, except *affinity*. Now we can conceive the attraction of cohesion between the particles of a body to be so great as to prevent them altogether from obeying the impulse of affinity. That this actually happens in some cases cannot be doubted: for if pure alumina be formed into a paste, and heated sufficiently, it becomes so hard that no acid can act upon it; yet its nature is not in the least changed: by proper trituration, it may be again rendered soluble; and when precipitated from this new solution, it has recovered all its original properties. The effect of the fire, then, was merely to increase the cohesion, by separating all the water, and allowing the particles to approach nearer each other.

It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must tend to facilitate their chemical union with the particles

of other bodies. This is the reason that bodies combine more easily when held in solution by water, or when they have been previously reduced to a fine powder. Now caloric possesses the property of diminishing cohesion. And one reason why some bodies require a high temperature to cause them to combine is, that at a low temperature the attraction of *cohesion* is in them superior to that of affinity; accordingly, it becomes necessary to weaken that attraction by caloric till it becomes inferior to that of affinity. The quantity of caloric necessary for this purpose must vary according to the strength of the cohesion and of the affinity; it must be inversely as the affinity, and directly as the cohesion. Wherefore, if we knew precisely the force of the cohesion between the particles of any body, and of the affinity between the particles of that body and of any other, we could easily reduce the temperature necessary to calculation.

That caloric or temperature acts in this manner cannot be doubted, if we consider that other methods of diminishing the attraction of cohesion may be substituted for it with success. A large lump of charcoal, for instance, will not unite with oxygen at so low a temperature as the same charcoal will do when reduced to a very fine powder; and charcoal will combine with oxygen at a still lower temperature, if it be reduced to its integrant particles, by precipitating it from alcohol, as Dr Priestley did by passing the alcohol through red hot copper. And to shew that there is nothing in the nature of oxygen and carbon which renders a high temperature necessary for their union, if they be presented to each other in different circumstances, they combine at the common temperature of the atmosphere; for if nitric acid, at the temperature of 60°, be poured upon charcoal powder, well dried in a close crucible, the charcoal takes fire, owing to its combining with the oxygen of the acid*: And in some other situations carbon is so completely divided, that it is capable of combining with the oxygen of the atmosphere, or, which is the same thing, of catching fire at the common temperature. This seems to be the case with it in those pyrophori that are formed by distilling to dryness several of the neutral salts which contain acetous acid†. These observations are sufficient to shew that caloric is in many cases necessary in order to diminish the attraction of *cohesion*.

But there is a difficulty still remaining, How comes it that certain bodies will combine with oxygen without the assistance of any foreign heat, provided the combination be once begun, though a quantity of caloric is necessary to begin the combination? and that other bodies require to be surrounded by a great quantity of caloric during the whole time of their combining with oxygen? Alcohol, for instance, if once kindled, burns till it is quite consumed; and this is the case with oils also, provided they be furnished with a wick.

We must observe, in the first place, that we would err very much, were we to suppose that a high temperature is not as necessary to these substances during the whole of their combustion as at the commencement of it; for Mr Mongé found, on making the trial, that a candle would not burn after the temperature of the air around it was reduced below a certain point.

All substances which continue to burn after being once kindled are *volatile*, and they burn the easier in proportion

Affinity.

* Proust and Morveau, *Encyc. Méthod. Chim.* i. 474.

† Morveau, *ibid.*

Affinity. proportion to that volatility. The application of a certain quantity of caloric to alcohol volatilizes part of it; that is to say, diminishes the attraction of its cohesion so much that it combines with oxygen. The oxygen which enters into this combination gives out as much heat as volatilizes another portion of the alcohol; which combines with oxygen in its turn; more heat is given out; and thus the process goes on. Oils and tallow exhibit the very same phenomena; only as they are less volatile, it is necessary to assist the process by means of the capillary attraction of the wick, which confines the action of the caloric evolved to a small quantity of oil, and thus enables it to produce the proper effect. In short, then, every substance which is capable of continuing to burn, after being once kindled, is volatile, or capable of being converted into vapour by the degree of heat at first applied. The reason that a live coal will not burn when suspended insulated in the air, is not, as Dr Hutton supposed*, because its *light* is dissipated; but because the coal cannot be converted into vapour by the degree of heat which it contains, and because the cohesion of its particles is too great to allow it to combine with oxygen without some such change. There are some coals, however, which contain such a quantity of bitumen that they will burn even in the situation supposed by Dr Hutton, and continue to burn, provided they be furnished with any thing to act as a wick. It is needless to add, that bitumen, like oil, is easily converted into vapour.

* On Light and Heat.

But this explanation, instead of removing our difficulties, has only served to increase them: For if caloric only acts by diminishing the attraction of cohesion, and converting these substances into vapour, why do not all elastic fluids combine at once without any additional caloric? why do not oxygen and hydrogen, when mixed together in the state of gas, unite at once and form water? and why do not oxygen and azot, which are constantly in contact in the atmosphere, unite also and form nitrous gas? Surely it cannot be the attraction of cohesion that prevents this union. And if it be ascribed to their being already combined with caloric, how comes it that an additional dose of one of the ingredients of a compound decomposes it? Surely, as Mr Mongé has observed, this is contrary to all the other operations in chemistry.

That the particles of fluids are not destitute of an attraction for each other, is evident from numberless facts. The particles of water draw one another after them in cases of capillary attraction; which is probably owing to the attraction of cohesion. It is owing to the attraction of cohesion, too, that small quantities of water form themselves into spheres: Nor is this attraction so weak as not to be perceptible. If a small plate of glass be laid upon a globule of mercury, the globule, notwithstanding the pressure, continues to preserve its round figure. If the plate be gradually charged with weights one after another, the mercury becomes thinner and thinner, and extends itself in the form of a plate; but as soon as the weights are removed, it recovers its globular figure again, and pushes up the glass before it. Here we see the at-

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traction of cohesion, not only superior to gravitation, but actually overcoming an external force*. And if the workman, after charging his plate of glass with weights, when he is forming mirrors, happens to remove these weights, the mercury which had been forced from under the glass, and was going to separate, is drawn back to its place, and the glass again pushed up. Nor is the attraction of cohesion confined to solids and liquids; it cannot be doubted, that it exists also in gases; at least it is evident, that there subsists an attraction between gases of a different kind: for although oxygen and azotic gas are of different gravities, and ought therefore to occupy different parts of the atmosphere, we find them always mixed together; and this can only be ascribed to an attraction. And were we to allow, with Humbolt and several other chemists, that these two gases are chemically combined in atmospherical air, an opinion contradicted by a late experiment in France (F); still the existence of carbonic acid gas in every part of the atmosphere can only be ascribed (if the inaccuracy of the expression may be tolerated) to a kind of cohesion. And whoever has been accustomed to pneumatic experiments, must have observed that small portions of *air*, as well as water, form themselves into spheres, and that the attraction of cohesion is so strong in gases, that large globules of them often adhere by a single point to the bottom of vessels filled with heavy fluids: whereas, had there been no attraction of cohesion, every part of the globule ought to have ascended to the surface of the fluid, except the particles immediately in contact with the vessel. Allowing, then, that there is an attraction of cohesion between the particles of gases, let us see whether that will not assist us in removing the difficulty.

Affinity.
* Morveau, Affinité, p. 543.

583 Explained.

It seems evident, in the first place, that the affinity between the bases of the gases under consideration and oxygen is greater than their affinity for that dose of caloric which produces their elastic form; for when they are combined with oxygen, the same dose will not separate them again. Let us take hydrogen for an instance: The affinity of hydrogen is greater for oxygen than for the caloric which gives it its gaseous form; but the oxygen is also combined with caloric, and there exists an attraction of cohesion between the particles of the hydrogen gas; the same attraction subsists between those of oxygen gas. Now the sum of all these affinities, namely, the affinity between hydrogen and caloric, the affinity between oxygen and caloric, the cohesion of the particles of the hydrogen, and the cohesion of the particles of oxygen—is greater than the affinity between the hydrogen and oxygen; and therefore no decomposition can take place. Let the affinity between

Oxygen and caloric	-	-	-	50
Hydrogen and caloric	-	-	-	50
Cohesion of oxygen	-	-	-	4
Cohesion of hydrogen	-	-	-	2

Sum of quiescent affinities, - - - 106
The affinity of oxygen and hydrogen, - 105
The quiescent affinities being greater than the divellent affinities, no decomposition can take place.

Y y

Let

(F) Air brought by means of a balloon from a great height in the atmosphere was found to contain less oxygen gas than the same quantity of air near the ground.

Let now a quantity of caloric be added to the oxygen and hydrogen gas, it has the property of expanding them, and of course of diminishing their cohesion; while its affinity for them is so small that it may be neglected. Let us suppose that it diminishes the cohesion of the oxygen 1, and of the hydrogen also 1, their cohesion will now be 3 and 1; and the quiescent affinities being only 104, while the divellent are 105, the decomposition would of course take place, and a quantity of caloric would thus be set at liberty to produce the same effects upon the neighbouring particles.

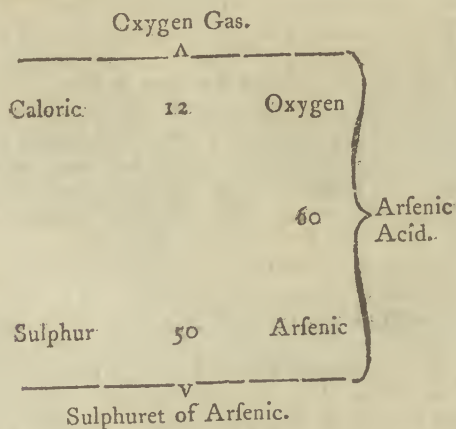
Thus, then, caloric acts only by diminishing cohesion: And the reason that it is required so much in gaseous substances, and in those combinations into which oxygen enters, is the strong affinity of oxygen and the other bases of the gases for caloric; for, owing to the repulsion which exists between the particles of that subtle substance, an effect is produced by adding large doses of it, contrary to what happens in other cases. The more of it is accumulated, the stronger is the repulsion between its particles; and therefore the more powerful is its tendency to fly off: and as this tendency is opposed by its affinity for the body and the cohesion of its particles, it must diminish both these attractions.

Though we have thus attempted to explain what has been always considered as one of the most difficult problems in chemistry, we are far from supposing that we have removed every difficulty. Much still remains to be done before the action of light and caloric can be fully understood; and there may be other agents, of whose existence we have not yet even conceived the idea.

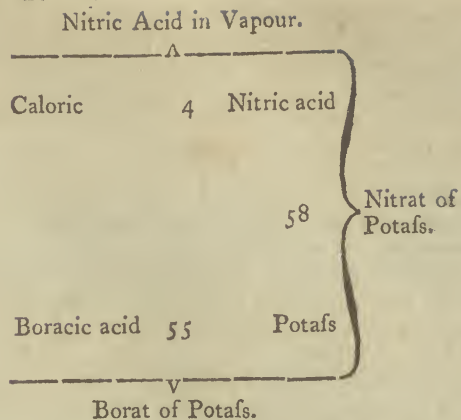
One difficulty still remains to be examined. Heat not only produces the combination of some bodies, but also occasions the decomposition of others. How does it act in these cases?

⁵⁸⁴ How heat decomposes bodies. That many of these decompositions are produced by chemical affinity, will be evident from the following examples.

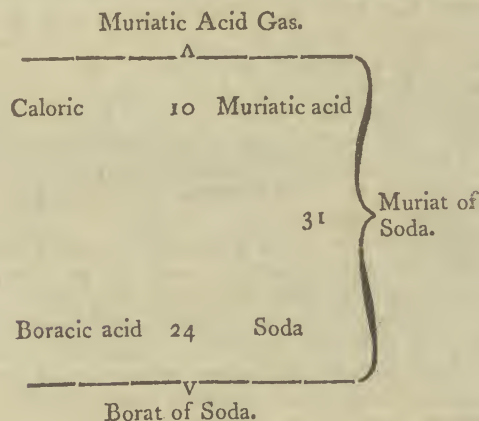
* *Pellatier*. When sulphur and arsenic acid are exposed to heat, sulphuret of arsenic is formed * evidently by a kind of compound affinity.



In the same manner, when nitrat of potash and boracic acid are exposed to heat, the nitric acid is volatilized, and borat of potash is left behind.



By the same compound affinity boracic acid and heat decomposes muriat of soda.



In the same manner, it would be easy to explain how all the decompositions by the *dry way*, as it is called, are produced.

But how comes caloric to decompose water after having produced the union of oxygen and hydrogen? The union, we have seen, was probably brought about by the play of opposite affinities; but in the separation, caloric seems to act by its peculiar power, or the repulsion which exists between its particles. When caloric combines with an integrant particle of water, this repulsion must separate the component parts somewhat from one another; consequently it must weaken their affinity; for every increase of distance produces that effect. Now let us suppose that the affinity between oxygen and hydrogen is 105, and that the affinity between caloric and each of these bodies is 50: as soon as the particles of oxygen and hydrogen are so far separated from each other that their affinity is less than 100, they will unite with caloric in preference, because the sum of their affinities for caloric is equal to 100; consequently, whenever that takes place water will be decomposed. Hence we see the reason why more heat is always necessary to produce the decomposition of bodies than what produced their union.

Caloric possesses another singular property, that of changing the compound affinities of bodies, even when it

Affinity. it does not appear to enter as an ingredient. What we mean will appear evident from the following examples :

Muriat of ammonia, } decompose each other at the
Carbonat of magnesia, } ordinary temperature of the
atmosphere, and form muriat of magnesia and carbonat
of ammonia: but, on the contrary,

Muriat of magnesia, and } decompose each other at
Carbonat of ammonia, } a high temperature; for
instance, at 212°. The products are muriat of ammonia
and carbonat of magnesia*.

* *Westrumb, Ann. de Chim. ii. 118.*
Again, if muriat of soda and sulphat of magnesia be mixed together at a low temperature, for instance at zero, they decompose each other, and muriat of magnesia and sulphat of soda are formed; but no decomposition takes place at a temperature above 32°.—Muriat of soda, and sulphat of alumina, exhibit precisely the same phenomena †.

† *Scheele and Gren, Ann. de Chim. xxiii. 291.*
Lastly, sulphat of magnesia and carbonat of ammonia decompose each other at the ordinary temperature; but at 212° the carbonic acid flies off, and the remaining substances form a triple salt ‡.

‡ *Fourcroy, Ann. de Chim. ii. 291.*
The last of these phenomena appears owing to the affinity between carbonic acid and caloric, and the two first to the affinity between muriat of ammonia and caloric, for that salt is volatilized.

It would not be so easy to explain the mutual decomposition of muriat of soda and sulphat of magnesia at a low temperature. It is probably connected with the alterations in the distance of the ingredients of chemical compounds, which are produced by the presence and absence of caloric.

From the important part which caloric acts in chemical combinations, Count Rumford has been lately induced to suspect that this subtle fluid is the *only agent* by which they are produced.

That caloric is a *necessary agent* in all chemical decompositions and new combinations, we very readily al-

low; because we know no other cause except caloric to prevent the particles of bodies from actual contact; in which case decomposition would be impossible: and if this be the sense in which that ingenious philosopher ascribes chemical combinations to caloric, we very readily agree with him; but if he supposes that caloric is the *agent* by which the particles of bodies are brought near each other, and the *force* by which they adhere to one another, we cannot help thinking that he is mistaken: For that bodies, chemically combined, are kept near each other by some force, cannot possibly be denied. Now, what is that force? We have said, after Newton, an *attraction between the particles themselves*; acknowledging, at the same time, that we are unable to explain what that is.

Count Rumford seems to suppose that there is no such thing as attraction between the particles themselves, but that caloric is the agent which keeps them together. If so, how does caloric perform this office? For our part, we do not pretend to understand it any more than the nature of attraction; nor do we see that it is possible to render it more intelligible. But there is another question of still greater importance, What are the proofs that caloric is the only agent in all cases of chemical combinations? For our part, we can think of no proof that can render this opinion in the smallest degree plausible.

Has this celebrated and candid philosopher considered this subject with his usual accuracy? If heat be a body, it cannot surely be the cause of affinity, unless it be possessed of properties which, so far from being proved, have not even been suspected. On the contrary, if it be a property of matter, what property is it? If it be a peculiar motion, as Count Rumford suspects, we would ask if it be possible for any motion whatever, independent of attraction, to produce the permanent union of two bodies?

PART III. OF DOUBLY COMPOUND BODIES.

THE bodies which consist of combinations of those substances that have been denominated *compound*, and which, for that reason, we have ventured to call *doubly compound bodies*, may be reduced to three classes:

Soaps,
Neutral salts,
Hydrofulphurets.

These shall form the subject of the three following Chapters; and we shall finish this part of the article with some observations on *crystallization*.

CHAP. I. Of Soaps.

THE compounds into which *oils* enter without decomposition have been denominated *soaps*.

Oils are capable of combining with alkalies, earths, and metallic oxides; they are capable also of combining with several of the acids. There are therefore two classes of soaps; 1. Alkaline, earthy, and metallic soaps, which, for the sake of brevity, we shall call *alkaline soaps*; and,

2. Acid soaps. These two classes form the subject of the two following Sections.

SECT. I. Of Alkaline Soaps.

As there are a great number of oils, all or most of which are capable of combining with alkalies, earths, and oxides, it is natural to suppose that there are as many genera of alkaline soaps as there are oils. That there are differences in the nature of soaps corresponding to the oil which enters into their composition, is certain; but these differences are not of sufficient importance to require very particular description. We shall therefore describe all the alkaline soaps together, and notice, as we go along, some of the most important differences resulting from the oily ingredients.

1. Soap of soda, or common soap. The word *soap* ³⁸⁶ Common (*sapo, σαπων*) first occurs in the works of Pliny and Galen, and is evidently derived from the old German word *sepe* (G). Pliny informs us, that soap was first discovered by the Gauls; that it was composed of tallow
Y y 2 and

(G) *Beckmann's History of Inventions*, III. 239.—A similar word is still used by the common people of Scotland.

Alkaline
Soaps.

and ashes; and that the German soap was reckoned the best*.

* *Pliny*,
lib. xviii.
c. 51.
537
Method of
forming it.

Soap may be prepared by the following process. A quantity of the soda of commerce, which is a carbonat of soda, and which is often called *barilla* from the name of a plant, by burning which it is procured in great quantities in Spain, is pounded and mixed in a wooden vessel, with about a fifth part of its weight of lime, slacked and passed through a sieve immediately before. Upon this mixture a quantity of water is poured, considerably more than what is sufficient to cover it, and allowed to remain on it for several hours. The lime attracts the carbonic acid from the soda, and the water becomes strongly impregnated with the pure alkali. This water is then drawn off by means of a stop-cock, and called the *first ley*. Its specific gravity should be about 1,200.

Another quantity of water is then to be poured upon the soda, which, after standing two or three hours, is also to be drawn off by means of the stop-cock, and called the *second ley*.

Another portion of water is poured on; and after standing a sufficient time, is drawn off like the other two, and called the *third ley*.

Another portion of water may still be poured on, in order to be certain that the whole of the soda is dissolved; and this weak ley may be put aside, and employed afterwards in forming the first ley in subsequent operations.

A quantity of oil, equal to six times the weight of the soda used, is then to be put into the boiler, together with a portion of the *third* or *weakest ley*, and the mixture must be kept boiling, and agitated constantly by means of a wooden instrument. The whole of the third ley is to be added at intervals to the mixture; and after it is consumed, the *second ley* must be added in the same manner. The oil becomes milky, combines with the alkali, and after some hours it begins to acquire consistence. A little of the *first ley* is then to be added, not forgetting to agitate the mixture constantly. Portions of the first ley are to be added at intervals; the soapy substance acquires gradually greater consistency, and at last it begins to separate from the watery part of the mixture. A quantity of common salt is then to be added, which renders the separation much more complete. The boiling is to be continued still for two hours, and then the fire must be withdrawn, and the liquor must be no longer agitated. After some hours repose the soap separates completely from the watery part, and swims upon the surface of the liquor. The watery part is then to be drawn off; and as it contains a quantity of carbonat of soda, it ought to be reserved for future use.

The fire is then to be kindled again; and, in order to facilitate the melting of the soap, a little water, or rather weak ley, is to be added to it. As soon as it boils, the remainder of the first ley is to be added to it at intervals. When the soap has been brought to the proper consistence, which is judged of by taking out small portions of it and allowing it to cool, it is to be withdrawn from the fire, and the watery part separated from it as before. It is then to be heated again, and a

little water mixed with it, that it may form a proper paste. It is then to be poured into the vessels proper for cooling it; in the bottom of which there ought to be a little chalk in powder, to prevent the soap from attaching itself to it. In a few days the soap will have acquired sufficient consistence to be taken out, and formed into proper cakes (H).

The use of the common salt in the above process is to separate the water from the soap; for common salt has a stronger affinity for water than soap has.

Olive oil has been found to answer best for making soap, and next to it perhaps tallow may be placed: but a great variety of other oils may be employed for that purpose, as appears from the experiments of the French chemists above quoted. They found, however, that lintseed oil and whale oil were not proper for making *hard soaps*, though they might be employed with advantage in the manufacture of *soft soaps*. Whale oil has been long used by the Dutch for this last purpose.

Soap may also be made without the assistance of heat; but in that case a much longer time and a larger proportion of alkali is necessary.

Manufacturers have contrived various methods of sophisticating soap, or of adding ingredients which increase its weight without increasing its value. The most common substance used for that purpose is water; which may be added in considerable quantities, especially to soap made with tallow (the ingredient used in this country), without diminishing its consistency. This fraud may be easily detected, by allowing the soap to lie for some time exposed to the air. The water will evaporate from it, and its quantity will be discovered by the diminishing of the weight of the soap. As soap sophisticated in this manner would lose its water by being kept, manufacturers, in order to prevent that, keep their soap in saturated solutions of common salt; which do not dissolve the soap, and at the same time, by preventing all evaporation, preserve, or rather increase, the weight of the soap. Messrs Darcet, Lelievre, and Pelletier, took two pieces equal in weight of soap sophisticated in this manner, and placed the one in a dry place in the open air, and the other in a saturated solution of common salt. After a month, the first had lost $\frac{56}{100}$ of its weight, the other had gained about $\frac{10}{100}$ parts*. Various other methods have been fallen upon to sophisticate soap; but as they are not, we hope, generally known, it would be doing an injury to the public to describe them here.

Different chemists have analysed soap, in order to ascertain the proportions of its ingredients; but the result of their experiments is various, because they used soap containing various quantities of water. From the experiments of Darcet, Lelievre, and Pelletier, it appears that soap newly made and exposed to sale contains

9,75 Oil,
1,37 Alkali,
4,87 Water.

Soap is soluble both in water and in alcohol. Its properties as a detergent are too well known to require any description.

It

(H) See the *Memoir of Darcet, Lelievre, and Pelletier*, in the *Ann. de Chim.* XIX. 253.

Alkaline
Soaps.588
Its sophisticati-
cation.* *Ann. de
Chim.* xix.
336.589
Proportion
of its ingre-
dients.

Alkaline
Soaps.

It is decomposed by lime, and by compound affinity (1) by sulphat of lime, nitrat of lime, muriat of lime, and probably all the salts which contain lime.

590
Soft soap.

2. Soap of potash.—Potash may be substituted for soda in making soap, and in that case precisely the same process is to be followed. It is remarkable, that when potash is used, the soap does not assume a solid form; its consistence is never greater than that of hog's lard. This is what in this country is called *soft soap*. Its properties as a detergent do not differ materially from those of *hard soap*, but it is not nearly so convenient for use. The alkali employed by the ancient Gauls and Germans in the formation of soap was potash: hence we see the reason that it is described by the Romans as an unguent.

Some persons have affirmed that they knew a method of making hard soap with potash. Their method is this: After forming the soap in the manner above described, they add to it a large quantity of common salt, boil it for some time, and the soap becomes solid when cooled in the usual way. That this method may be practised with success has been ascertained by Messrs Darcet, Lelievre, and Pelletier; but then the hard soap thus formed does not contain potash, but soda; for when the common salt (muriat of soda) is added, the potash of the soap decomposes it, and combines with its muriatic acid, while at the same time the soda of the salt combines with the oil, and forms hard soap: and the muriat of potash formed by this double decomposition is dissolved in the water, and drawn off along with it*.

* Ann. de
Chim. xix.
322.

Chaptal has lately proposed to substitute wool in place of oil in the making of soap. The ley is formed in the usual manner, and made boiling hot, and shreds of woollen cloth of any kind are gradually thrown into it; they are soon dissolved. New portions are to be added sparingly, and the mixture is to be constantly agitated. When no more cloth can be dissolved, the soap is made †. This soap is said to have been tried with success. It might doubtless be substituted for soap with advantage in several manufactures, provided it can be obtained at a cheaper rate than the soaps at present employed.

† Ibid. xxi.
27.

Fish, too, have been lately substituted for oil with equal success. The only disadvantage which soap made in this manner is liable to, is a disagreeable smell, from which it cannot easily be freed.

591
Soap of
ammonia.

3. Soap of ammonia.—This soap was first particularly attended to by Mr Berthollet. It may be formed by pouring carbonat of ammonia on soap of lime. A double decomposition takes place, and the soap of ammonia swims upon the surface of the liquor in the form of an oil; or it may be formed with still greater ease by pouring a solution of muriat of ammonia into common soap dissolved in water. We have formed it often by mixing caustic ammonia and oil †.

† Berthollet,
Mem. Par.
1780, or
Nicholson's
Journal, i.
170

It has a more pungent taste than common soap. Water dissolves a very small quantity of it; but it is easily dissolved in alcohol. When exposed to the air, it is gradually decomposed.

592
Soap of
lime.

4. Soap of lime.—This soap may be formed by pouring lime-water into a solution of common soap. It is

insoluble both in water and alcohol. Carbonat of fixed alkali decomposes it by compound affinity*. It melts with difficulty, and requires a strong heat.

Alkaline
Soaps.

5. Soap of magnesia.—This soap may be formed by mixing together solutions of common soap and sulphat of magnesia.

* Thouvenel.

593
Soap of
magnesia,

It is exceedingly white. It is unctuous, dries with difficulty, and preserves its whiteness after desiccation. It is insoluble in boiling water. Alcohol and fixed oil dissolve it in considerable quantity. Water renders its solution in alcohol milky. A moderate heat melts it; a transparent mass is formed, slightly yellow, and very brittle †.

† Berthollet,
ibid.

6. Soap of alumina.—This soap may be formed by mixing together solutions of alum and of common soap. It is a flexible soft substance, which retains its suppleness and tenacity when dry. It is insoluble in alcohol, water, and oil. Heat easily melts it, and reduces it to a beautiful transparent yellowish mass ‡.

594
Of alumina,

† Ibid.

7. Soap of barytes resembles almost exactly the soap of lime §.

595
Of barytes,
§ Ibid.
596

8. Soap of mercury.—This soap may be formed by mixing together a solution of common soap and of corrosive muriat of mercury. The liquor becomes milky, and the soap of mercury is gradually precipitated. This soap is viscid, not easily dried, loses its white colour when exposed to the air, and acquires a slate colour, which gradually becomes deeper, especially if exposed to the sun or to heat. It dissolves very well in oil, but sparingly in alcohol. It readily becomes soft and fluid when heated ||.

|| Ibid.
597
Of zinc,

9. Soap of zinc.—This soap may be formed by mixing together a solution of sulphat of zinc and of soap. It is of a white colour, inclining to yellow. It dries speedily, and becomes friable ¶.

¶ Ibid.
598
Of cobalt,

10. Soap of cobalt.—This soap, made by mixing nitrat of cobalt and common soap, is of a dull leaden colour, and dries with difficulty, though its parts are not connected.

Mr Berthollet observed, that towards the end of the precipitation there fell down some green coagula, much more consistent than soap of cobalt. These he supposed to be a soap of nickel, which is generally mixed with cobalt*.

599
Of nickel,

11. Soap of tin.—It may be formed by mixing common soap with a solution of tin in nitro-muriatic acid. It is white. Heat does not fuse it like other metallic soaps, but decomposes it †.

* Ibid.
600
Of tin,

12. Soap of iron.—Formed by means of sulphat of iron. It is of a reddish brown colour, tenacious, and easily fusible. When spread upon wood, it sinks in and dries. It is easily soluble in oil, especially of turpentine. † Berthollet proposes it as a varnish ‡.

† Ibid.
601
Of iron,

13. Soap of copper.—Formed by means of sulphat of copper. It is of a green colour, has the feel of a resin, and becomes dry and brittle. Hot alcohol renders its colour deeper, but scarcely dissolves it. Ether dissolves it, liquefies it, and renders its colour deeper and more beautiful. It is very soluble in oils, and gives them a pleasant green colour §.

† Ibid.
602
Of copper,

14. Soap of lead.—It may be formed by means of acetite

§ Ibid.
603
Of lead,

(1) In this and the following chapter, *compound affinity* is not taken always in its strict and proper sense, but is applied to all those decompositions in which the affinities of more than three bodies act.

Alkaline Soaps. acetite of lead. It is white, tenacious, and very adhesive when heated. When fused, it is transparent, and becomes somewhat yellow if the heat be increased*.

* *Bartollet, ibid.* 604
Of silver, 15. Soap of silver.—It may be formed by means of nitrat of silver. It is at first white, but becomes reddish by exposure to the air. When fused, its surface becomes covered with a very brilliant iris; beneath the surface it is black †.

† *Ibid.* 605
Of gold, 16. Soap of gold.—It is at first white, and of the consistence of cream. It gradually assumes a dirty purple colour, and adheres to the skin so that it is difficult to efface the impression †.

† *Ibid.* 606
And of manganese, 17. Soap of manganese.—It is at first white, but it assumes in the air a reddish colour, owing evidently to the absorption of oxygen. It speedily dries to a hard brittle substance, and by liquefaction assumes a brown blackish colour ‡.

§ *Ibid.* We owe the following resinous soaps to Mr Mezaize.

607
Soap of turpentine and potash, 18. Soap of turpentine and potash.—576 grains of turpentine were dissolved in 9216 grains of alcohol, and then 576 grains of potash were added. The alcohol was distilled off at a boiling water heat. There remained in the retort 648 grains of a brownish soapy matter, which when spread on glass appeared transparent. There remained also nearly the same quantity of potash dissolved in water. This soap was put in a vessel for six weeks; during which time 72 grains of solution of potash separated from it. It had assumed the consistence of honey. Its colour was browner. It was completely soluble in water: the solution was milky. It dissolved also in alcohol. It had no disagreeable taste. Vinegar decomposed it.

608
Soap of benzoin, 19. Soap of benzoin and potash.—By treating 9216 grains of alcohol, 1728 grains of benzoin, and 576 grains of potash, as above, 1728 grains of a soap were obtained, browner than that of turpentine, of an odour a little aromatic. When left in a cellar for six weeks, it became solid. Its solution in water was yellowish. Vinegar decomposed it. This compound is the same with Starkey's soap.

609
Of balm of Peru, 20. Soap of balm of Peru and potash.—1152 grains of balm, 2304 grains of potash, and 9216 grains of alcohol, produced a soap of a reddish colour, and pretty consistent.

610
Of guaiac, 21. Soap of guaiac and potash.—1728 grains of guaiac was dissolved in 18648 grains of alcohol, and the solution filtered, and to this 1728 grains of potash were added, and the soap obtained as above. It was solid, of a brown colour at first, which afterwards became green on the surface, but remained unaltered within. Its solution in water was greenish. It had no disagreeable taste. It dissolved in alcohol, and formed a green tincture. Vinegar decomposed it.

611
And of scammony, 22. Soap of scammony and potash.—By the above process a soap was obtained with scammony pretty consistent, of a brown colour, soluble in water, and not decomposed by the water of pits from which selenites is obtained. It has no disagreeable taste. Its solution in alcohol is of a deep amber colour ||.

¶ *Jour. de Phys.* xv. 441.

612
Method of forming acid soaps.

SECT. II. Of Acid Soaps.

SULPHURIC acid may be combined with oils in the following manner: Put two ounces of it into a glass mortar, and add, by little and little, three ounces of the

oil nearly boiling hot, triturating it constantly. A substance is obtained of the consistence of turpentine. Dissolve it in about six ounces of boiling water, and the soap will unite into a mass as the water cools. If it still contain an excess of acid, dissolve it again in boiling water, and continue this process till the soap is perfectly neutralized.

613
Acid soap of lintseed oil, 1. Soap of sulphuric acid and lintseed oil.—It dissolves entirely in water. The solution is opaque, of a bluish white colour, viscid, and frothes when agitated. Alcohol dissolves it. The solution is transparent and brown. Potash decomposes it, forming sulphat of potash. The oil swims on the top, of the consistence of wax. Ammonia decomposes it; and if too much be added it forms soap of ammonia. Magnesia, lime, nitric acid, and muriatic acid, also decompose it. Distilled, it yielded a few drops of water and an oil, which coagulated, and was of the consistence of wax.

614
Of almond oil, 2. Soap of sulphuric acid and oil of almonds.—Soluble in water; solution milky. Frothes. Soluble in alcohol; solution brown and transparent. Potash, lime, nitric acid, muriatic acid, sulphurous acid (the oil separated assumed the consistence of turpentine), tartar, acedulous oxalat of potash, sal ammoniac, muriat of lead and zinc decompose it. It is not decomposed by vinegar, boracic acid, acetite of ammonia, borax, copper, tin, nor lead. When distilled, there passed over a little water and an oil, which coagulated and smelt very rancid: there remained behind a coal.

615
Of olive oil, 3. Soap of sulphuric acid and olive oil.—It is brown, and of the consistence of wax. Solution in hot water white, opaque, viscid; frothes. Solution in alcohol transparent and brown. Potash, ammonia, magnesia, nitric acid, muriatic acid, vinegar, nitre, sal ammoniac, acetite of lead and white oxide of lead, decompose it.

616
Of butter, 4. Soap of sulphuric acid and butter of cacao.—It is hard, and marbled like Venice soap. Solution in water of grey, opaque, viscid; frothes. Solution in alcohol yellow and transparent. Potash, ammonia, nitric, muriatic, and acedulous acids, tartar, sal ammoniac, tartrate of potash, acetite of lead, and zinc in powder, decompose it. When distilled, there came over water, an oil that coagulated, and a few drops of a black oil, which also congealed: both were rancid.

617
Of wax, 5. Soap of sulphuric acid and wax.—It is white, and becomes very hard. Its solution in water is white, and opaque, and frothes: Its solution in alcohol is yellow and transparent. Potash, ammonia, nitric and muriatic acids, decompose it.

618
Of spermaceti, 6. Soap of sulphuric acid and spermaceti.—It is brown. It dissolves in water: the solution is milky, viscid, and frothes on agitation. It dissolves in alcohol; the solution is transparent and yellow. It is decomposed by as much alkali as saturates the acid: if more be added, it unites with the oil, and forms a new soap. Lime and magnesia decompose it. The oil is also separated, and appears in the form of a coagulum on adding to the solution nitric acid, muriatic acid, tartar, nitre, nitrat of soda, common salt, and zinc in powder; but not on adding vinegar, tin, lead.

619
Of oil of eggs, 7. Soap of sulphuric acid and oil of eggs.—Its solution in water is white, opaque, viscid; frothes: that in alcohol yellow and transparent. Alkalies decompose it; but if too much be added a new soap is formed. Nitric and muriatic acids separate the oil of the consistence of wax,

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Sulphats.

Neutral Salts.

wax, the first yellow, the last a deep brown. Nitre, sal ammoniac, acetite of lead, iron filings, zinc powder, decompose it; vinegar, borax, filings of lead do not.

To unite this acid with the essential oils, three ounces were put into a glass mortar, and four ounces of the oil were added drop by drop, and care taken to prevent its becoming hot: equal parts of water were then poured on, and the whole heated slowly nearly to the temperature of boiling water: on cooling, the soap united into a brown mass.

620 Of turpentine,

8. Soap of sulphuric acid and turpentine. It is brown, and of the consistence of soft wax. Its solution in water is grey, opaque, viscid; frothes: Its solution in alcohol is brown and transparent. Alkalies decompose it: with too much it forms at the boiling heat a new soap.

Nitric and muriatic acids separated the oil thickened, as did also white oxide of lead, muriat of lead, muriat of soda and iron filings; but acetic acid, boracic acid, tartrate of potash, and tin filings, produced no such effect.

621 And of amber oil.

9. Soap of sulphuric acid and amber oil.—Its solution in water and alcohol as in the last soap. Alkalies, magnesia, and lime, decomposed it. Nitric and muriatic acids separated the oil of the consistence of wax. Tartar, sal ammoniac, muriat of antimony, acetite of lead, iron filings, decomposed it; vinegar, acetite of ammonia, and lead did not.

• Journ. de Phys. xvi. 409.

Mr Achard, to whom we owe these soaps*, could not succeed in his attempts to form soaps with nitric and muriatic acids.

CHAP. II. Of NEUTRAL SALTS.

622 Salt explained.

THE word salt has been used in chemistry in a very extensive, and not very definite sense. Every body which is sapid, easily melted, soluble in water, and not combustible, has been called a salt.

Salts were considered by the older chemists as a class of bodies intermediate between earths and water. Many disputes arose about what bodies ought to be comprehended under this class, and what ought to be excluded from it. Acids and alkalies were allowed by all to be salts; but the difficulty was to determine concerning earths and metals. Several of the earths possess all the properties which have been ascribed to salts; and the metals are capable of entering into combinations which possess saline properties. It is needless for us to enter into this dispute at present, as we have taken the liberty, in imitation of some of the best modern chemists, to expunge the class of salts altogether, and to arrange those subordinate classes, which are usually referred to it, under distinct heads.

623 Neutral salt explained.

The word neutral salt was originally applied exclusively to combinations of acids and alkalies, which were considered as substances possessing neither the properties of acids nor alkalies, but properties intermediate between the two. But the word is now always taken in a more extensive sense, and signifies all compounds formed by the combination of acids with alkalies, earths, or metallic oxides. In these compounds, the earth, alkali, or oxide, is denominated the base. Each order of salts is

denominated after the acid which enters into its composition; and every individual salt is distinguished by subjoining the name of its base. Thus all the salts into which sulphuric acid enters are called sulphats, and the salt formed by the combination of sulphuric acid and potash is called sulphat of potash.

It is evident, then, that there must be as many orders of neutral salts as there are acids; and as many salts in each order as there are alkalies, earths, and metallic oxides, supposing every acid capable of combining with every one of these substances. But besides these simple combinations of one acid and one base, there are others more complex, composed of two acids combined with one base, or two bases combined with one acid, or a neutral salt combined with an acid or a base. These combinations have been called triple salts; and they increase the number of neutral salts very considerably.

In the following sections we shall take a short view of the properties of the principal neutral salts at present known; for this wide and important region of chemistry is still very far from being completely explored.

SECT. I. Of Sulphats.

SULPHURIC acid is capable of combining with all the alkalies, with alkaline earths, alumina, jargonina, and the greater number of the metallic oxides. The principal neutral salts which it forms are as follows:

614

1. Sulphat of potash.—This salt may be formed by saturating diluted potash with sulphuric acid, and then evaporating the solution gently till crystals are formed. It seems to have been known at a very early period by chemists, and a great variety of names were given to it, according to the manner of forming it, or the fancy of the operator. Some of these names were, *specificum purgans*, *nitrum fixum*, *arcantum duplicatum*, *panacea bolsatica*, *sal de duobus*, *sal polychrest glaseri*, &c.; but it was commonly known by the name of *vitriolated tartar* till the French chemists called it *sulphat of potash*, when they formed their new nomenclature in 1787 (K).

Sulphat of potash.

When the solution of sulphat of potash is sufficiently diluted, it affords by evaporation hexahedral pyramids, or short hexangular prisms, terminated by one or more hexangular pyramids. But these crystals vary much in their figure, according to the care with which they are prepared.

625

It has a very disagreeable bitter taste. Its specific gravity is 2,298*.

* Brisson.

It is soluble in the temperature of 60° in 16 times its weight of water; in a boiling heat, it is soluble in 5 times its weight †.

† Bergman.

According to Bergman, it is composed of 40 parts of acid, 52 parts of alkali, and 8 of water; but according to Kirwan, whose experiment has been already described, it is composed of 45 parts of acid and 55 of alkali.

It suffers no alteration in the air. When placed upon burning coals, it breaks into pieces with a noise resembling a number of small explosions succeeding each other at short intervals (L), but suffers no other alteration. In a red heat it melts.

It has hitherto been applied to little use. It is a purgative,

(K) Bergman called it *alkali vegetabile vitriolatam*, and Morveau *vitriol of potash*.
(L) This is called *deceppitation*.

Sulphats. purgative, but its disagreeable taste prevents it from being much employed for that purpose.

It often has an excess of acid, owing, as Mr Bergman and Morveau have very ingeniously explained, to an affinity which exists between this salt and sulphuric acid.

It is decomposed by compound affinity by the following salts :

Nitrat of soda (M),	Nitrat of silver,
———— lime,	———— lead,
———— barytes*,	Acetite of barytes,
———— strontites †,	Muriat of lime ‡,
———— ammonia,	———— lead §,
———— magnesia,	———— magnesia?
———— mercury,	———— soda .

It is sometimes luminous in the dark, as Mr Giobert has observed ¶.

2. Sulphat of soda.—This salt was first discovered by Glauber a German chemist, and for that reason was long known by the name of *Glauber's salt*. He himself called it *sal mirabile*. It may be prepared by saturating soda with sulphuric acid, but is more usually obtained by decomposing common salt in order to procure muriatic acid.

Its crystals are transparent, and when formed by slow evaporation, are six-sided prisms terminated by dihedral summits.

Its taste at first has some resemblance to that of common salt, but soon becomes very disagreeably bitter.

It is soluble in 2,67 times its weight of water at the temperature of 60°, and in 0,8 of boiling water.

It is composed, according to Bergman, of 27 parts of acid, 15 of alkali, and 58 of water; but, according to the experiments of Kirwan, of 22 parts of acid, 17 of alkali, and 61 of water.

When exposed to the air, it loses great part of its water, and falls into a white powder (N).

When exposed to heat, it first undergoes the *watery fusion* (O), then its water is evaporated, it is reduced to a white powder, and at last in a red heat it melts. Mr Kirwan has observed, that part of the acid, as well as the water, is driven off by the application of a strong heat*.

This salt is used as a purgative.

It often combines with an excess of acid.

It is decomposed by compound affinity, by the following substances :

Nitrat of lime,	Acetite of barytes,
———— magnesia,	———— potash,
Muriat of potash,	———— lime,
———— soda,	Carbonat of barytes,
———— magnesia,	———— potash.
———— lime †,	

3. Sulphat of ammonia.—This salt was discovered by Glauber, and called by him *secret sal ammoniac*. It was also called *vitriolated ammoniac*. It may be prepared by saturating ammonia with sulphuric acid.

Its crystals are generally small six-sided prisms, whose planes are unequal, terminated by six-sided pyramids.

It has a sharp bitter taste.

It is soluble in twice its own weight of water at the temperature of 60°, and in its own weight of boiling water.

According to Mr Kirwan, it is composed of 29,7 of alkali, 55,7 of sulphuric acid, and 14,16 of water*.

When exposed to the air, it slowly attracts moisture. * *Irish Trans. ibid.*

When heated, it first decrepitates, then melts, and in close vessels sublimates, but with some loss of its alkali †. † *Kirwan's Mineral. ii x*

It has not hitherto been applied to any use.

It is apt to contain an excess of acid.

It is decomposed by compound affinity by the following salts :

Nitrat of lime,	Acetite of soda,
———— magnesia,	———— barytes,
———— mercury?	———— lime,
Muriat of potash,	———— magnesia,
———— soda,	Carbonat of potash,
———— barytes,	———— soda,
———— lime,	———— barytes,
———— magnesia,	———— lime,
———— mercury*,	———— magnesia,
Acetite of potash,	Phosphat of lime †.

4. Sulphat of barytes.—This substance was first discovered by Scheele. It abounds in nature. It is generally in the form of a hard, very heavy, stone.

It is sometimes found crystallized; but the variety of forms is so great that they baffle all description. *¶ Bergman, † Delleskamp Ann de Chim. vi. 37. 628 Sulphat of barytes.*

It is soluble in 43,000 times its weight of water at the temperature of the atmosphere ||.

Sulphuric acid dissolves it when concentrated and boiling, but it is precipitated by the addition of water. || *Kirwan's Min. i. 136.*

When exposed to heat it melts, and, if the heat be very strong, gradually dissipates.

After being heated red hot, it has the property of being luminous in the dark. This was first observed ⁶²⁹ *Bologna stone.*

in a variety of this substance known by the name of Bologna stone. Lemery informs us, that this property was first discovered by an Italian shoemaker named Vincenzo Casciarolo. This man found a Bologna stone at the foot of Mount Paterno, and its brightness and gravity made him suppose that it contained silver. Having exposed it to the fire, doubtless in order to extract from it the precious metal, he observed that it was luminous in the dark. Struck with the discovery, he repeated the experiment, and it constantly succeeded with him.

From an experiment of Mr Klaproth, it appears to be composed of 33 parts of acid and 77 of barytes.

It is decomposed by compound affinity by the following salts :

Nitrat of soda,	Nitrat of magnesia,
———— lime,	Carbonat of potash,
———— ammonia,	———— soda*.

5. Sulphat of lime.—This substance was well known to the ancients under the name *gypsum*; but the composition of gypsum was not known till Margraf and Macquer analysed it, and proved that it was composed of sulphuric acid and lime. The artificial compound *¶ Afzelius. 630 Sulphat of lime.*

(M) Most of these double decompositions in this and the following sections are inserted on the authority of Morveau. See his Table of *Affinity*, page 360 of this article.

(N) This is called *efflorescing*.

(O) When substances melt by means of the water they contain on the application of heat, they are said to undergo the *watery fusion*.

* Kirwan.
† Id.
‡ Bergman.
§ Id.
|| Fuchs,
Ann. de Chim. vi.
29.

¶ Ann. de Chim. x. 40.
626
Sulphat of soda.

* Irish
Trans. iv.

‡ Scheele.
627
Sulphat of ammonia.

Sulphat. pound formed by the union of these two bodies was formerly called *selenite*.

It is found crystallized in various forms, sometimes transparent and sometimes opaque; and when pure it is of a white colour.

It has a slightly nauseous taste, scarcely perceptible except by drinking a glass of water impregnated with

* *Macquer.* it *

It is soluble in 500 parts of water at the temperature of 60°, but much more soluble in boiling water.

It is composed, according to Bergman, of 46 parts of acid, 32 of earth, and 22 of water: according to the late experiments of Mr Kirwan, when so far dried as still to retain its glassy appearance, it contains 48 of acid, 34 of earth, and 18 of water; which differs very little from the determination of Bergman.

It is not affected by exposure to the air.

It is soluble in sulphuric acid.

When exposed to heat, it undergoes a kind of watery fusion, but afterwards it cannot be melted by the strongest heat. In a clay crucible indeed it fuses at 130° Wedgewood, owing evidently to the presence of the clay.

631
Plaster of Paris.

When heated red hot and cooled, it is called *plaster of Paris*; a substance so useful for casting moulds, &c. on account of its property of becoming solid almost immediately when reduced into a paste with water.

By compound affinity it is decomposed by the following substances:

Acetite of barytes,	Carbonat of potafs,
———— potafs,	———— soda,
Carbonat of barytes,	———— magnesia?
	———— alumina†.

† *Bergman.*
632
Sulphat of frontites

6. Sulphat of frontites. This salt, first formed by Dr Hope, is a white powder destitute of taste. It is soluble in 3840 parts of boiling water. Sulphuric acid dissolves it readily when assisted by heat, but it is precipitated by the addition of water to the solution †.

‡ *Dr Hope,*
Trans. Edin.
iv. 10.

7. Sulphat of magnesia. This salt was first observed in the springs at Epsom in England by Grew in 1675; but Dr Black was the first who accurately ascertained its composition. It has been called *Epsom salt*, *sal catharticus amarus*, and *Seydler salt*.

It crystallizes in quadrangular prisms, whose plains are equal, surmounted by quadrangular pyramids.

It has an excessively bitter taste.

At the temperature of 60° it is soluble in its own weight of water, and in 4ths of its weight of boiling water. The volume of water is increased 4th by adding the salt §.

§ *Bergman.*

It is insoluble in alcohol.

It is composed, according to Bergman, of 19 parts of earth, 33 of acid, and 48 of water; according to Mr Kirwan, of 17 parts of earth, 29,46 of acid, and 53,54 of water.

When exposed to the air it effloresces, and is reduced to powder.

When exposed to heat it undergoes the watery fusion, and by increasing the temperature its water is eva-

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porated, but it cannot be decomposed by means of Sulphats. heat.

It is sometimes employed as a cathartic, but its chief use is to furnish magnesia by its decomposition.

It is decomposed by compound affinity by the following salts.

Muriat of potafs,	Acetite of lime,
———— soda (P),	Carbonat of barytes,
———— lime,	———— potafs,
Acetite of barytes,	———— soda*,
———— potafs,	———— ammonia (Q).

* *Bergman.*

634

8. Sulphat of ammonia and magnesia. This triple salt was discovered by Mr Fourcroy. Into the solution of 100 parts of sulphat of magnesia in 500 parts of water, 12 parts of ammonia being poured, a very small quantity of magnesia was precipitated, and a considerable quantity more on the addition of another dose of ammonia; but farther additions had no effect. From the magnesia precipitated, it appeared that 38 parts of the sulphat had been decomposed. There remained, therefore, 62 parts in solution, mixed with a large quantity of ammonia. By evaporation, 92 parts of a white transparent rhomboidal salt were obtained, evidently composed of sulphuric acid, ammonia, and magnesia, in the proportions that would have formed 62 parts of sulphat of magnesia and 30 of sulphat of ammonia, and probably consisting of a combination of these two sulphats †.

Sulphat of ammonia and magnesia.

9. Sulphat of alumina. This salt may be formed by dissolving alumina in sulphuric acid. It has an astringent taste, is very soluble in water, and crystallizes in thin plates which have very little consistence †. Little attention has hitherto been paid to this salt, which was never properly distinguished from *alum* till two memoirs, one by Vauquelin and another by Chaptal, on the nature of alum, made their appearance in the 22d volume of the *Annales de Chimie*. This salt generally contains an excess of acid, and is not neutralized without considerable difficulty §.

† *Ann. de Chim.* iv. 211.

635
Sulphat of alumina.

‡ *Vauquelin,*
Ann. de Chim. xxii. 277. and
Chaptal,
ibid. 294.

§ *Ibid.* p. 277.

10. Sulphat of alumina and potafs, or alum. The *στυπτηρις* of the Greeks, and the *alumen* of the Romans, was a native substance, which appears to have been nearly related to *green vitriol* or *sulphat of iron*; and which consequently was very different from what we at present denominate *alum*. From the researches of Professor Beckmann, it appears that we owe the discovery of alum to the Asiatics; but at what period, or by what means, the discovery was made, is altogether unknown.

636
Alum.

It continued to be imported from the East till the 15th century, when a number of alum works were established in Italy. In the 16th century it was manufactured in Germany and Spain; and during Queen Elizabeth's reign an alum work was established in England by Thomas Chalmer.

The alum of commerce is usually obtained from earths containing sulphur and clay, or sulphuric acid and clay.

The composition of alum has been but lately understood ⁶³⁷Its composition,

Z z

(P) Only below the temperature of 32°. *Scheele, Gren, Ann. de Chim.* xxiii.

(Q) Only below the temperature of 212°. *Fourcroy, Ibid.* ii. 291.

Sulphats. flood with accuracy. It has been long known, indeed, that one of its ingredients is sulphuric acid (R); and the experiments of Geoffroy, Hellot, Pot, Margraf, and Macquer, proved incontrovertibly that alumina is another ingredient. But sulphuric acid and alumina are incapable of forming alum: Manufacturers knew, that the addition of a quantity of potash, or of ammonia, or of some substance containing these alkalies, is almost always necessary; and it was proved, that in every case in which such additions are unnecessary, the earth from which the alum is obtained contained already a quantity of potash. Various conjectures were made about the part which potash acts in this case; but Chaptal and Vauquelin appear to have been the first chemists that ascertained, by decisive experiments, that alum was a triple salt, composed of sulphat of alumina and of potash united together (s).

638
And properties.

Alum crystallizes in large octahedrons, composed of two tetrahedral pyramids, applied to each other at their bases.

It has a sweetish and astringent taste, and always reddens the tincture of turnsole.

* Neumann and Chaptal. It is soluble at the temperature of 60°, in from 10* to 15 † times its own weight of water, according to its purity; pure alum being most insoluble. Seventy-five † Kirwan and Chaptal. parts of boiling-water dissolve 100 of alum ‡. ‡ Bergman.

§ Kirwan's Min. ii. 14. A hundred parts of alum contain, according to Kirwan, 17,62 parts of acid, 18 of earth (and alkali), and 64,38 of water §.

When exposed to the air it effloresces slightly.

When exposed to a gentle heat it undergoes the watery fusion. A strong heat causes it to swell and foam, and to lose about 44 per cent. of its weight, consisting chiefly of water of crystallization||. What remains is called *calcined* or *burnt alum*, and is sometimes used as a corrosive.

|| Ibid.

Alum is of great importance as a mordant in dyeing, and is used also in several other arts.

By compound affinity it is decomposed by the following salts.

Nitrat of soda,	Acetite of potash,
_____ lime,	_____ soda,
_____ ammonia,	_____ lime,
_____ magnesia,	_____ ammonia,
Muriat of barytes,	_____ magnesia,
_____ potash,	Carbonat of barytes,
_____ soda,	_____ potash,
_____ lime,	_____ soda,
_____ ammonia,	_____ lime,
_____ magnesia,	_____ ammonia,
Acetite of barytes,	_____ magnesia.

Sulphats. melted together in an iron ladle, and the mixture dried till it becomes blackish and ceases to swell; if it be then pounded small, put into a glass phial, and placed in a sand-bath till a blue flame issues from the mouth of the phial, and after burning for a minute or two be allowed to cool (τ), a substance is obtained known by the name of *Hombert's pyrophorus*, which has the property of catching fire whenever it is exposed to the open air, especially if the air be moist.

This substance was accidentally discovered by Hombert about the beginning of the 18th century, while he was engaged in his experiments on the human fæces. He had distilled a mixture of human fæces and alum till he could obtain nothing more from it by means of heat; and four or five days after, while he was taking the residuum out of the retort, he was surprised to see it take fire spontaneously. Soon after Lemery the Younger discovered that honey, sugar, flour, or almost any animal or vegetable matter, could be substituted for human fæces; and afterwards Mr Lejoy de Suvigny shewed that several other salts containing sulphuric acid might be substituted for alum*. Scheele proved, that alum deprived of potash was incapable of forming pyrophorus, and that sulphat of potash might be substituted for alum †. And Mr Proust has shewn, that a number of neutral salts, composed of vegetable acids and alkalies, or earths, when distilled by a strong fire in a retort, left a residuum which took fire spontaneously on exposure to the air. * See Macquer's *Diç.* † Scheele on Fire, and on Pyrophorus.

These facts have thrown a great deal of light on the nature of Hombert's pyrophorus, and enabled us in some measure to account for its spontaneous inflammation. It has been ascertained, that part of the sulphuric acid is decomposed during the formation of the pyrophorus, and of course a part of the alkaline base becomes uncombined with acid, and the carbon, which gives it its black colour, is evidently divided into very minute particles. It has been ascertained, that during the combustion of the pyrophorus a quantity of oxygen is absorbed. The inflammation seems to be owing to a *disposing affinity*. Part of the carbon and of the sulphur attract oxygen from the atmosphere, in order to combine with the potash, and the caloric disengaged produces a temperature sufficiently high to kindle the rest of the carbon.

Alum is capable of combining with alumina, and of forming what has been called *alum saturated with its earth*, which is an insoluble, tasteless, earthy-like substance.

It is capable also, as Chaptal informs us, of combining with several other bases, and of forming many triple salts, which have never yet been examined with attention ‡.

639
Hombert's pyrophorus.

If three parts of alum and one of flour or sugar be

‡ Ann. de Chim. xxii. 293.

(R) Some chemists have thought proper to call the sulphuric acid, obtained by distilling alum, *spirit of alum*.
(s) This they did in the two memoirs above quoted, and which were first published in the 22d volume of the *Annales de Chimie*. An account of Vauquelin's memoir has been already given under the article ALUM in this Supplement. Chaptal's memoir is no less interesting. This celebrated chemist appears, from the facts stated in the 23d volume of the *Annales*, p. 222. to have made his discovery before Vauquelin: who, however, was ignorant of what Chaptal had done, as he informs us in the *Ann. de Chim.* xxv. 107. that his paper was read to the Institute a fortnight before that of Chaptal's came to Paris. He informs us, too, that Descroisilles had long before made the same discovery, and that he had published it in Berthollet's *Art de la Teinture*.

(τ) Care must be taken not to keep it too long exposed to the heat.

Sulphats. 11. Sulphat of jargonia (v). In order to combine jargonia with acids, they should be poured upon it while it is yet moist, after being precipitated from some of its solvents; for after it is dry, acids do not act upon it without difficulty. By this method sulphat of jargonia is easily formed. It is white, and without sensible taste. Heat expels the acid from it, and the jargonia remains in a state of purity. At a high temperature charcoal converts it into a sulphuret, which is soluble in water, and which, by evaporation, furnishes crystals of hydrofulphuret (τ) of jargonia*.

* Vauquelin, Ann. de Chim. xxii. 199.
† Four. de Phys. xxxvi. 187.

641 Green sulphat of iron.

† Lib. xxxiv. c. 12.

§ Bergman.

Klaproth informs us, that with excess of acid sulphat of jargonia forms transparent stelliform crystals, soluble in water, and having an astringent taste †.

12. Sulphat of iron. There are two sulphats of iron, which were first accurately distinguished by Mr Proust. The one contains the green oxide, the other the red oxide of iron. We shall, in imitation of Mr Proust, denominate them from their colours.

The green sulphat of iron.—This salt, which is composed of sulphuric acid and green oxide of iron, is found native, and was known to the ancients. It is mentioned by Pliny under the names of *misy*, *sory*, *calchaantum* ‡. It was formerly called *green vitriol*.

It is generally prepared by exposing native sulphuret of iron, a very abundant mineral, to air and moisture.

Its crystals are of a light green colour, and in the form of rhomboidal parallelipeds.

It has a sharp astringent taste.

It is soluble in six times its weight of water at the temperature of 60°, and in ¼ths of its weight of boiling water §.

It is insoluble in alcohol.

According to Bergman, it is composed of 39 parts

of acid, 23 of oxide, and 38 of water; but according to Mr Kirwan, of 26 parts of acid, 28 (v) of oxide, and 46 of water.

Sulphats.

When exposed to the air, it effloresces; but if it be moistened, it is gradually converted into red sulphat of iron.

When heated, it first assumes a yellow colour, loses its water and its acid; if the heat be increased, nothing remains but a yellow powder.

The Prussic alkali precipitates from the solution of this salt a white powder, which gradually becomes blue by attracting oxygen*.

* Proust.

It is used in dyeing, and in making ink, &c.

It is decomposed by compound affinity by

- Nitrat of silver,
- Muriat of soda †.

† Ballen and Tutben, Ann. de Chim. xi. 320.

The red sulphat of iron may be formed by exposing a solution of green sulphat to the air, or by treating it with nitric acid. It was formerly called *mother water of vitriol*.

Little is known of its properties, except that it is deliquescent, incrySTALLIZABLE, and soluble in alcohol.

642 Red sulphat of iron.

It was first accurately examined by Mr Proust.

The green sulphat of iron generally contains some of it, which may be separated by means of alcohol.

It is alone capable of forming Prussian blue with the Prussic acid, and of striking a black colour with the gallic acid ‡.

We have observed, that when it is diluted with water, and an excess of sulphuric acid is poured in, it is again slowly converted into green sulphat.

† See Proust's paper, Nicholson's Journal, i. 435.

13. Sulphat of zinc.—This salt, according to the best accounts, was discovered at Rammelsberg in Germany, about the middle of the 16th century. Many

643 Sulphat of zinc.

Z z z

ascribe

(v) *Jargonia*, or, as the French chemists call it, *zirconia*, has been discovered in great abundance in France by Morveau, who found that the hyacinths of Expailly contained more than half their weight of it. From Vauquelin's analysis they appear to be composed of

- 32 parts of filica,
- 64 jargonia,
- 2 oxide of iron.

Jargonia has been examined with great care by these two philosophers, the experiments of Klaproth have been confirmed, and several new properties of it have been discovered. Perhaps a more detailed account than we have hitherto given of this new earth may not be unacceptable to our readers.

Jargonia is a white powder, its specific gravity is considerable, it has a feel resembling that of filica, it has no taste, and is insoluble in water. When separated from its solutions by pure alkalies, it retains, when exposed to the air to dry, a pretty considerable quantity of water, which renders it transparent, and gives it a resemblance to gum arabic both in its colour and fracture.

When exposed to the heat of the blow-pipe it does not melt; but Vauquelin melted it by exposing it surrounded with charcoal in a porcelain crucible to an intense heat for an hour and a half. Its specific gravity was then 4.35, its colour was grey, and its hardness such that it was capable of scratching glass. It melts with borax, and forms a transparent and colourless glass; but phosphat of soda and the fixed alkalies do not attack it.

It is insoluble in the fixed alkalies, has very little affinity for carbonic acid, and is precipitated from its solutions together with iron by the Prussic alkali.

Its affinities, as far as they have been ascertained by Vauquelin, are as follows:

- Vegetable acids; order unknown,
- Sulphuric acid,
- Muriatic,
- Nitric.

See upon this subject the Memoirs of Morveau and Vauquelin, *Ann. de Chim.* xxi. 72. and xxii. 179.

(τ) These curious salts form the subject of the next chapter.

(v) Perhaps the quantity of oxide is somewhat over-rated here; for before it was examined by Mr Kirwan, it had assumed a red colour: it must therefore have been converted into the brown or red oxide by attracting oxygen from the atmosphere.

Sulphats. ascribe the invention to Julius Duke of Brunswick. Henkel and Neumann were the first chemists who proved that it contained zinc; and Brandt first ascertained its composition completely*. It is generally formed for commercial purposes from sulphuret of zinc or *blende*, as it is called. This salt is called also *white vitriol*.

* Beckmann's Hist. of Inventions, art. Zinc.

It is of a white colour, and its crystals are rhomboidal prisms, terminated by quadrangular pyramids: there is generally a slight defect in two of the opposite angles of the prism, which produces a quadrangular section †. Its specific gravity is 2,000.

† Bergman, ii. 327.

It has a sharp styptic taste.

It is soluble in 2,28 parts of water at the temperature of 60°; but in a much smaller quantity of boiling water ‡.

‡ Ibid.

It is composed, according to Bergman, of 40 (v) parts of acid, 20 of oxide, and 40 of water: Kirwan supposes that it is composed of 12 parts of acid, 26,4 of zinc, 20 of oxide, 41,6 of water (w).

According to Bergman, this salt is not altered in the air; others affirm that it effloresces. This, no doubt, depends upon the place where it is kept.

Heat decomposes this salt.

644 Sulphat of manganese.

14. Sulphat of manganese.—This salt was first obtained by Scheele (x): It is composed of sulphuric acid and white oxide of manganese.

§ Scheele,

Its crystals are oblique parallelepipeds; they are of a white colour, and very bitter §.

These crystals are decomposed by a strong red heat, and the sulphuric is converted into sulphurous acid by the oxide attracting its oxygen, and being changed into black oxide ||.

|| Id. 645 Sulphat of nickel.

15. Sulphat of nickel.—This salt, which is composed of sulphuric acid and oxide of nickel, was first described by Bergman. Its crystals are in the form of decahedrons, composed of two quadrangular truncated pyramids; they are of a green colour ¶.

¶ Bergman, ii. 268.

646 Sulphat of cobalt.

16. Sulphat of cobalt.—This salt was first mentioned by Mr Brandt. Its crystals are of a reddish colour; but if any nickel be present, they are green.

647 Sulphat of lead.

17. Sulphat of lead.—This salt has been long known: it is composed of sulphuric acid and white oxide of lead. The crystals are white, small, and most commonly needle-shaped: according to Sage, they are tetrahedral prisms.

It is soluble in 18 parts of water,

Heat decomposes it.—It is very caustic.

* Monnet. 648 Sulphat of copper.

18. Sulphat of tin.—Nothing is known concerning this salt, except that it crystallizes in fine needles interlaced with one another*.

19. Sulphat of copper.—This salt appears to have been known to the ancients. It is generally obtained by evaporating those waters which naturally contain it. It is called also *blue vitriol*.

Its crystals are of a deep blue colour; they are in the form of oblong rhomboids. Its specific gravity is 2,230.

It has a very strong styptic taste; and indeed is employed as a caustic.

It is soluble in four parts of water at the tempera-

ture of 60°; but in a much smaller quantity of boiling water*.

Sulphats.

* Bergman.

It is composed, according to Bergman, of 46 parts of acid, 26 of oxide of copper, and 28 of water. Kirwan supposes it to contain 27,68 of acid, 35 of oxide, and 37,32 of water †.

† Miner. ii.

When exposed to the air, it effloresces, and is covered with a yellowish grey powder.

It requires a very strong heat to decompose it.

It has the property of communicating a green colour to flame.

It is used in the preparation of several paints, and for a variety of other purposes.

It is decomposed by compound affinity by acetite of lead.

20. Sulphat of bismuth.—Little is known of this salt, except that it is with difficulty crystallized, and is very deliquescent.

649 Sulphat of bismuth.

21. Sulphat of antimony.—This salt does not crystallize. It is easily decomposed by heat.

650 Antimony.

22. Sulphat of arsenic.—This salt is scarcely known. It does not appear to be crystallizable. It is decomposed by water.

651 Arsenic.

23. White sulphat of mercury.—This salt may be formed by boiling together two parts of mercury and three of concentrated sulphuric acid, and stopping the process whenever the mercury is converted into a white mass.

652 White sulphat of mercury.

This mass, in order to remove the excess of acid, is to be washed repeatedly with small portions of water, till it ceases to redden turnsole. The sulphat of mercury, thus obtained, is very white. Its crystals are either small plates or prisms. Its taste is not very caustic. It is soluble in 500 parts of water at the temperature of 55°, and in 287 parts of boiling water. It is composed of 83 parts of white oxide of mercury, 12 of sulphuric acid, and 5 of water †. It is not altered by exposure to the air. Heat decomposes it.

† Fourcroy, Ann. de Chim. x. 299.

This sulphat is capable of combining with a new portion of acid: It was in that state before it was washed with water. This salt, which may be called *acidulous white sulphat of mercury*, has a very caustic taste, and is corrosive. It reddens vegetable blues. It is soluble in 157 parts of water at the temperature of 55°, and in 33 parts of boiling water §.

24. Yellow sulphat of mercury.—This salt may be obtained by continuing to boil the preceding mixture of mercury and sulphuric acid till the mercury assumes a yellow colour. It appears to be composed of yellow oxide of mercury and a small portion of sulphuric acid. It is soluble in 2000 parts of water at the temperature of 55°, and in 600 parts of boiling water. The solution is colourless. It was formerly called *turbith mineral* ||.

§ Fourcroy, ibid.

653 Yellow sulphat of mercury.

25. Sulphat of ammonia and mercury.—This triple salt may be formed by pouring ammonia into a solution of sulphat of mercury. If only a small quantity of ammonia be used, a copious blackish precipitate takes place, part of which is converted into running mercury by exposure to light; and consequently is black oxide of mercury; the remaining part is the triple salt. If a large quantity of ammonia be used, only the black oxide

|| Fourcroy, ibid.

654 Sulphat of ammonia and mercury.

(v) There is evidently some mistake in this statement; it does not correspond with what he says elsewhere.

(w) *Mineralogy*, ii. 24. We do not understand this statement.

(x) Westfield, indeed, obtained it; but he mistook it for sulphat of magnesia.

Sulphats. is precipitated; for the triple salt is rendered much more soluble by an excess of ammonia. As this excess evaporates, the salt crystallizes. The crystals are polygons, very brilliant and hard. It has a sharp, austere, metallic taste. It has no peculiar odour. It is scarcely soluble, except with excess of ammonia. It is composed, according to Fourcroy's analysis, of 18 parts of sulphuric acid, 33 of ammonia, and 39 of oxide of mercury. Heat decomposes it. The products obtained by distilling it are, a little ammonia, azotic gas, a little pure mercury, some *sulphite of ammonia*; and there remains yellow sulphat of mercury*.

* Fourcroy, *ibid.*

This triple salt may be formed also by pouring ammonia upon acidulous sulphat of mercury, or on yellow sulphat of mercury †.

† *Ibid.* 655
Sulphat of silver.

26. Sulphat of silver.—This salt is formed by pouring sulphuric acid on oxide of silver. Its crystals are small needles. It melts when exposed to a strong heat, but does not sublime.

† Bergman.

It is decomposed by muriat of lead ‡.

27. Sulphat of gold.—This salt is unknown.

28. Sulphat of platinum.—Unknown.

29. Sulphat of tungsten.—Probably no such combination is possible.

30. Sulphat of molybdenum.—Probably impossible.

656
Sulphat of uranium.

31. Sulphat of uranium.—This salt was first formed by Mr Klaproth. He formed it by pouring sulphuric acid on the oxide of uranium. Nothing farther is known of it, except that its crystals are small, and of a yellow colour.

657
Titanium.

32. Sulphat of titanium.—This salt was first formed by Mr McGregor. It does not appear, from Klaproth's experiments, to be crystallizable.

658
Tellurium.

33. Sulphat of tellurium.—When one part of tellurium is mixed cold in a well-stopped vessel with a hundred parts of concentrated sulphuric acid, the latter gradually assumes a beautiful crimson red colour: when a small quantity of water is added, drop by drop, the colour disappears, and the metal is precipitated in the form of black flakes. The solution is destroyed by heat, the colour disappears, and the metal separates in the state of a white oxide. When sulphuric acid is diluted with two or three parts of water, and a small quantity of nitric acid is added, it dissolves a considerable quantity of tellurium. The solution is transparent and colourless, and is not decomposed by the addition of a larger quantity of water §.

§ Klaproth, *Philosophical Mag.* i. 80.

SECT. II. Of Sulphites.

SALTS composed of sulphurous acid united respectively with alkalis, earths, or oxides, are called *sulphites*. Those hitherto examined are the following:

659
Sulphite of potass.

1. Sulphite of potass.—This salt was first formed by Stahl; but was first accurately described by Berthollet, Fourcroy, and Vauquelin.

It may be formed by passing sulphurous acid into a saturated solution of carbonate of potass till all effervescence ceases. The solution becomes hot, and crystallizes by cooling ||.

|| Fourcroy, and Vauquelin, *Nicholson's Journ.* i. 317.

Its crystals are white and transparent; their figure that of rhomboidal plates. Its crystallization often presents small needles diverging from a common centre ¶.

¶ *Ibid.*

Its taste is penetrating and sulphurous. At the common temperature of the atmosphere, it is soluble in its own weight of water, but much more soluble in boiling water.

When exposed to the air, it effloresces, becomes opaque and hard, and is gradually converted into *sulphat of potass* by absorbing oxygen.

Sulphites.

When exposed to a sudden heat, it decrepitates, loses its water: at a red heat some sulphurous vapours are emitted; at last a portion of sulphur separates, and the residuum is sulphat of potass, with a slight excess of alkali.

Nitric and oxy-muriatic acids convert it into sulphat of potass by imparting oxygen.

It decomposes the oxides of gold, silver, mercury, the red oxide of lead, the black oxide of manganese, and the brown oxide of iron. When the green oxide of iron and the white oxide of iron are boiled with it in water, and an acid added, a precipitate takes place of these bodies united to some sulphur, and the salt is converted into a sulphat: at the same time sulphurated hydrogen gas is emitted.

By compound affinity it is decomposed by

All salts with base of soda, except the borat and carbonate;

All metallic salts except carbonats;

All neutral salts whose acid has a stronger affinity for potass than sulphurous acid has*.

* *Ibid.* 660
Sulphite of soda.

2. Sulphite of soda.—This salt was first accurately described by Fourcroy and Vauquelin.

It is white and perfectly transparent. Its crystals are four-sided prisms, with two very broad sides and two very narrow ones, terminated by dehedral pyramids.

Its taste is cool and sulphurous.

It is soluble in four times its weight of cold water, but it is more soluble in hot water.

It is composed of 18,8 parts of soda, 31,2 of acid, and 50 of water.

By exposure to air, it effloresces, and is slowly converted into a sulphat.

When exposed to heat, it undergoes the watery fusion, and afterwards exhibits precisely the same phenomena as the sulphite of potass.

Metallic oxides and salts affect it precisely as they do sulphite of potass.

It is decomposed by compound affinity by carbonate of potass, and the other salts which decompose sulphite of potass †.

3. Sulphite of ammonia.—This salt was first described by Fourcroy and Vauquelin ‡.

† *Ibid.* 661
Sulphite of ammonia.

It crystallizes in six-sided prisms terminated by six-sided pyramids.

Its taste is cool and penetrating like that of the other ammoniacal salts, but it leaves a sulphurous impression in the mouth.

It is soluble in its own weight of cold water. Its solubility is increased by heat.

It is composed of 29,07 parts of ammonia, 60,06 of acid, and 10,87 of water.

When exposed to the air, it attracts moisture, and is soon converted into a sulphat.

Heat volatilizes it without decomposition.

Its habitudes with metallic oxides and salts are nearly the same with those of the above described sulphites, only it is capable of forming with several of them triple salts §.

662
Sulphite of barytes.

4. Sulphite of barytes.—This salt was first described by Berthollet ||.

|| *Ibid.* Ann. de Chim. ii. 57.

It is incrySTALLIZABLE; it has no perceptible taste; and is perfectly insoluble in water ¶.

¶ Fourcroy, and Vauquelin.

Sulphites

It is composed of 59 parts of barytes, 39 parts of acid, and 2 of water.

* *Ibid.*

It does not easily change into a sulphat by exposure to air; but heat produces this effect*.

663
Sulphite of lime.

5. Sulphite of lime.—This salt was first described by Berthollet †.

† *Ann. de Chim. ibid.*

Its crystals are six-sided prisms, terminated each by a very long pyramid ‡.

† *Fourcroy and Vauquelin.*

It has scarcely any taste; however, when kept long in the mouth, it communicates to the tongue a taste which is manifestly sulphurous.

It is very sparingly soluble in water, except with excess of acid.

It is composed of 47 parts of lime, 48 of sulphurous acid, and 5 of water.

By contact of air it is converted into a sulphat, but very slowly.

Heat converts it into a sulphat by depriving it of a portion of sulphur.

It is decomposed by compound affinity by

Carbonates of alkalies, Fluats of alkalies,
Phosphats of alkalies, Most metallic salts §.

§ *Ibid.*664
Sulphite of magnesia.

6. Sulphite of magnesia.—This salt was first described by Fourcroy and Vauquelin.

Its crystals are white and transparent, and in the form of depressed tetrahedrons.

Its taste is mild and earthy at first, and afterwards sulphurous.

It is sparingly soluble in water, except when there is an excess of acid.

It is composed of 16 parts of magnesia, 39 of acid, and 45 of water.

It becomes opaque when exposed to the air; is very slowly converted into a sulphat.

By exposure to heat, it softens, swells up, and becomes ductile like gum; a strong heat decomposes it altogether.

It is decomposed by

Alkaline salts,

Earthy salts, except those of alumina ||.

|| *Fourcroy and Vauquelin.*

7. Sulphite of alumina.—First formed by Berthollet.

665
Sulphite of alumina.

It does not crystallize, but is converted into a soft ductile mass. It is not soluble in water, but becomes abundantly so when there is an excess of acid.

It is composed of 44 parts of alumina, 32 of acid, and 24 of water.

¶ *Fourcroy and Vauquelin.*

Heat decomposes it ¶.

8. Sulphite of iron.—It was first formed by Berthollet.

666
Sulphite of iron.

Its crystals are white, and have but very little of the styptic taste of iron salts*.

* *Ann. de Chim. ii. 58.*

Berthollet also formed the sulphites of zinc and tin, but he has not described them.

SECT. III. Of Nitrats.

THOSE salts, in the composition of which the nitric acid forms one ingredient, are called *nitrats*.

667

Nitric.

1. Nitrat of potash, nitre, or saltpetre.—As this salt is produced naturally in considerable quantities, particularly in Egypt, it is highly probable that the ancients were acquainted with it; but scarcely any thing certain can be collected from their writings. If Pliny mentions it at all, he confounds it with soda, which was known by the names of *nitron* and *nitrum*. It is certain, however, that it has been known in the east from

time immemorial. Roger Bacon mentions this salt in the 13th century under the name of *nitre*.

Nitrats.

It crystallizes in slender oblong hexagonal prisms, often striated, terminated by hexagonal pyramids obliquely truncated. Its specific gravity is 1,920.

Its taste is sharp, bitterish, and cooling.

It is soluble in seven times its weight of water at the temperature of 60°, and in nearly its own weight of boiling water*.

* *Bergman.*

According to Bergman, it is composed of 31 parts of acid, 61 of potash, and 8 of water; but this proportion of acid is undoubtedly too small. According to Mr Kirwan, it is composed of 41,2 of acid, 46,15 of alkali, and 12,65 of water †.

† *Mineral. ii. 27.*

It is not altered by exposure to the air.

When exposed to a strong heat, it melts; and congeals by cooling into an opaque mass, which has been called *mineral crystal*. If the heat be continued, the acid is gradually decomposed and driven off. When the solution of nitre is exposed to a boiling heat, part of the salt is evaporated along with the water, as Wallerius, Kirwan, and Lavoisier, observed successively. When nitre is exposed to heat along with many combustible substances, its acid is decomposed; the combustible seizes the oxygen, and at the same time a lively white flame appears, attended with a decrepitation: this is called the *detonation of nitre*.

Nitre mixed with charcoal and sulphur in proper proportions forms *gunpowder*.

Nitre is decomposed by compound affinities by

Acetite of barytes.

668

No phenomenon has excited the attention of chemical philosophers more than the continual reproduction of nitre in certain places after it had been extracted from them. Prodigious quantities of this salt are necessary for the purposes of war; and as Nature has not laid up great magazines of it as she has of some other salts, this annual reproduction is the only source from which it can be procured. It became, therefore, of the utmost consequence, if possible, to discover the means which Nature employed in forming it, in order to enable us to imitate her processes by art, or at least to accelerate and facilitate them at pleasure. Numerous attempts accordingly have been made to explain and to imitate these processes.

Reproduction of nitre.

Stahl, setting out on the principle that there is only one acid in nature, supposed that nitric acid is merely sulphuric acid combined with phlogiston; and that this combination is produced by putrefaction: he affirmed accordingly, that nitre is composed by uniting together potash, sulphuric acid, and phlogiston. But this opinion, which was merely supported by very far-fetched analogies, could not stand the test of a rigorous examination.

Lemery the Younger accordingly advanced another; affirming, that all the nitre obtained exists previously in animals and vegetables, and that it is formed in these substances by the processes of vegetation and animalization. But it was soon discovered that nitre exists, and is actually formed, in many places where no animal nor vegetable substance has been decomposed; and consequently this theory was as untenable as the former. So far indeed is it from being true that nitre is formed alone by these processes, that the quantity of nitre in plants has been found to depend entirely on the soil in which they grow †.

† *Bouillon.*

At

Nitrats.

Nitrats.

At last by the numerous experiments of several French philosophers, particularly by those of Thouvenel, it was discovered that nothing else is necessary for the production of nitre but a basis of lime, heat, and an open but not too free communication with dry atmospheric air. When these circumstances combine, the acid is first formed, and afterwards the alkali makes its appearance. How the air furnishes materials for this production is easily explained, now that the component parts of the nitric acid are known to be oxygen and azot. But how lime contributes to their union it is not so easy to see. It is a disposing affinity, which, like most others referred to that singular class, our present knowledge of the nature of affinity does not enable us to explain. The appearance of the potafs is equally extraordinary. If any thing can give countenance to the hypothesis, that potafs is composed of lime and azot, it is this singular fact.

Acetite of lime

Muriat of lime,

_____ magnesia,

_____ magnesia,

_____ alumina,

_____ alumina,

Muriat of barytes,

Carbonat of barytes,

_____ potafs,

_____ potafs,

_____ foda,

_____ foda.

672

4. Nitrat of barytes. This salt may be formed into hexagonal crystals, but it requires great address to produce them.

It attracts moisture from the atmosphere.

Heat decomposes it, and leaves pure barytes. The decomposition of this salt by heat is the most convenient method of procuring pure barytes yet known. It was first proposed by Mr Vauquelin.

By compound affinity it is decomposed by

Alkaline carbonats,

Oxalat of ammonia*.

* Bergman's

673

5. Nitrat of lime. This salt forms by crystallization six-sided prisms, terminated by dehdral pyramids, but more commonly small regular octahedral needles.

It has a sharp bitterish taste.

It is soluble in two parts of cold water, and in its own weight of boiling water.

Boiling alcohol dissolves its own weight of it †.

† Bergman.

According to Bergman, it is composed of 43 parts of acid, 32 of lime, and 25 of water. Kirwan has found, that 100 parts of lime require for saturation 180 parts of acid ‡.

‡ Miner. ii.

Nitrat of lime deliquesces when exposed to the air.

Heat decomposes it like all other nitrats.

By compound affinity it is decomposed by

Sulphat of barytes,

Acetite of potafs,

_____ potafs,

Carbonat of barytes,

_____ foda,

_____ potafs,

_____ ammonia,

_____ foda,

_____ alumina,

_____ ammonia,

Muriat of barytes,

_____ alumina,

_____ potafs,

_____ magnesia,

Acetite of barytes,

Tungstat of ammonia §.

§ Scheele.

6. Nitrat of stontites. This salt, first formed by Dr Hope, crystallizes readily, but the crystals are very irregular in their shape: sometimes they are hexagonal truncated pyramids; sometimes octahedrons, consisting of two four-sided pyramids united at their bases.

673

Nitrat of stontites.

It is soluble in its own weight of water, at the temperature of 60°, and in little more than half its weight of boiling water. It has a strong pungent taste.

In a dry air it effloresces, but in a moist air it deliquesces.

It deflagrates on hot coals. Subjected to heat in a crucible, it decrepitates gently, and then melts. In a red heat it boils, and the acid is dissipated. If a combustible substance be at this time brought into contact with it, a deflagration with a very vivid red flame is produced ||.

|| Hope,

Transf. Edin. iv. 12.

7. Nitrat of magnesia. The composition of this salt was first ascertained by Dr Black.

Its crystals are quadrangular prisms. It has a very bitter taste. It is very soluble in water. Alcohol dissolves 1/3th of its own weight of it ¶.

¶ Bergman,

iii. 381.

One hundred parts of magnesia require 255 of nitric acid for saturation*.

* Kirwan's.

It deliquesces in the air, according to Bergman; but Dijonval affirms, that he has procured it in crystals which rather effloresce.

It:

669
Nitrat of foda.

2. Nitrat of foda. This salt was called formerly *cubic nitre*.

It forms rhomboidal crystals. Its specific gravity is 1,870.

It has a cool sharp taste, and is somewhat more bitter than nitre.

It is soluble in about three parts of water at the temperature of 60°, and is scarcely more soluble in boiling water.

It is composed, according to Bergman, of 43 parts of acid, 32 of foda, and 25 of water. From an experiment formerly described, Mr Kirwan concludes, that it contains 57,65 of acid, and 42,35 of alkali; but perhaps the proportion of acid may be somewhat over-rated, as no direct proof has been brought that the salt contains no water.

When exposed to the air it rather attracts moisture. Its phenomena in the fire are the same with those of nitre, only it does not melt so easily.

It is decomposed by compound affinity by the following salts:

Sulphat of barytes,

Muriat of ammonia,

_____ potafs,

Acetite of barytes,

_____ alumina,

_____ potafs,

Muriat of barytes,

Carbonat of barytes,

_____ potafs,

_____ potafs.

_____ lime,

670
Nitrat of ammonia.

3. Nitrat of ammonia. This salt crystallizes with difficulty into regular needles. It was formerly called *nitrum semivolatile*, and *nitrum flammans*.

It has a sharp, acrid, somewhat urinous taste. It is soluble in about half its weight of boiling water.

It is composed of 58 parts of acid, about 26 of alkali, and 16 of water*.

* Kirwan.

When exposed to the air it deliquesces.

When exposed to heat, it first undergoes the watery fusion, afterwards detonates, and is completely decomposed. Berthollet has shewn, that this phenomenon is owing to the hydrogen of the alkali entering into combination with the oxygen of the acid, and forming water, while the acid flies off in a gaseous form.

By compound affinity it is decomposed by the following substances:

Sulphat of barytes,

Acetite of barytes,

_____ potafs,

_____ potafs,

_____ alumina,

_____ foda,

Nitrats.

It is decomposed by heat.

By compound affinity it is decomposed by—

Sulphat of barytes,	Muriat of lime,
———— potafs,	Acetite of barytes,
———— foda,	———— potafs,
———— ammonia,	———— foda,
———— alumina,	———— lime,
Muriat of barytes,	Carbonat of barytes,
———— potafs,	———— potafs,
———— foda,	———— lime.

675
Nitrats of ammonia and magnesia.

8. Nitrats of ammonia and magnesia. This triple salt was discovered by Mr Fourcroy. Into a saturated solution of nitrats of magnesia, containing 73 grains of magnesia, he poured ammonia as long as any precipitate could be obtained. Twenty-one grains of magnesia were precipitated, 52 grains remained combined with the acid and the ammonia. He found that 52 grains of magnesia produced, when saturated with nitric acid, 288 grains of nitrats; and that the quantity of nitric acid necessary to saturate 21 grains of magnesia, when saturated with ammonia, produced 84 grains of nitrats of ammonia. He concludes, therefore, though the data are not quite satisfactory, that the triple salt is composed of 288 grains of nitrats of magnesia, and 84 of nitrats of ammonia*.

* Ann. de Chim. iv. 215.

9. Nitrats of alumina. This seems to have been first attended to by Beaumé.

676
Nitrats of alumina.

Its crystals are pyramidal. It has a very astringent taste. It is soluble in water, and deliquesces in the air.

677
Nitrats of jargonina.

10. Nitrats of jargonina. This salt may be easily formed by pouring nitric acid on newly precipitated jargonina

It always contains an excess of acid. By evaporation a yellowish transparent matter is obtained, exceedingly tenacious and viscid, and which dries with difficulty. It has an astringent taste, and leaves on the tongue a viscid matter, owing to its being decomposed by the saliva. It is only very sparingly soluble in water; the greatest part remains under the form of gelatinous and transparent flakes. Like all the other salts into which jargonina enters, it is decomposed by heat. It is decomposed also by sulphuric acid, which occasions a white precipitate, soluble in excess of acid; by carbonat of ammonia, which produces a precipitate soluble by adding more carbonat; and by an infusion of nut-galls in alcohol, which produces a white precipitate, soluble in an excess of the infusion; unless the jargonina contains iron; in which case the precipitate is a greyish blue, and part of it remains insoluble, giving the liquor a blue colour. This liquor, mixed with carbonat of ammonia, produces a matter purple by transmitted light, but violet by reflected light. Gallic acid also precipitates nitrats of jargonina of a greyish blue, but the colour is not so fine. Most of the other vegetable acids decompose this salt, and form combinations insoluble in water †.

† Vauquelin, Ann. de Chim. xx i. 159.

678
Nitrats of iron.

11. Nitrats of iron. The green oxide of iron decomposes, but does not combine with nitric acid. The brown oxide forms with it a red or brown solution, which by evaporation may be reduced to a jelly, but will not crystallize.

679
Nitrats of zinc.

12. Nitrats of zinc. The oxide of zinc combines with nitric acid, and forms with it a salt which crystallizes in compressed and friated tetrahedral prisms, terminated by four-sided pyramids.

Its solution is exceedingly caustic. When placed on burning coals it melts and detonates as it dries. It can scarcely be dried without being in some measure decomposed.

It deliquesces in the air*.

13. Nitrats of manganese. This salt, composed of oxide of manganese and nitric acid, was first examined by Scheele. Its crystals are small and shining, of a very bitter taste, and soluble in water †.

14. Nitrats of cobalt. It is of a pale red colour, and crystallizes in needles. It deliquesces when exposed to the air. Heat decomposes it. When nickel is present, this salt assumes a green colour.

15. Nitrats of nickel. Its crystals are of a green colour, and in the form of rhomboidal cubes. They are deliquescent, and are gradually decomposed when exposed to the air, the acid leaving them ‡.

16. Nitrats of lead. Nitric acid combines with the white oxide of lead. The crystals of this salt are of a white colour; their form an irregular octagon, or rather truncated hexahedral pyramid. When exposed to heat it decrepitates, and melts with a yellowish flame. By compound affinity it is decomposed by

Muriat of potafs,	
———— foda,	
———— ammonia,	
Carbonat of foda §.	

17. Nitrats of tin. Tin is converted into an acid by nitric acid: it is not probable, therefore, that any permanent nitrats of tin can be formed.

18. Nitrats of copper. This salt appears to have been first obtained by Macquer.

Its form, when properly crystallized, is an oblong parallelogram. It is of a fine blue colour. It is exceedingly caustic. It melts at 77° ||.

It is deliquescent in a moist air, but in a dry place is covered with a green efflorescence. It is very soluble in water. Heat decomposes it.

19. Nitrats of bismuth. This salt crystallizes in various forms. Fourcroy obtained it in flattened rhomboids. It effloresces in the air. Water decomposes it. It detonates in the fire.

20. Nitrats of antimony. Little is known concerning this salt, except that it is very deliquescent, and is decomposed by heat.

21. Nitrats of arsenic. With white oxide of arsenic, nitric acid forms a salt which crystallizes. It is very deliquescent. It does not detonate.

22. Nitrats of mercury. This salt may be formed by dissolving mercury in nitric acid. It crystallizes in the cold in regular flat 14-sided figures; but their form differs according to the manner in which the crystallization has been performed.

It is soluble in water.

This salt is exceedingly caustic. It detonates on coals. When heated in a crucible it melts, and is decomposed. The oxide attracts oxygen from the acid, which flies off in the form of nitrous gas, and red oxide of mercury remains behind.

It is slowly decomposed also in the air. It is decomposed by compound affinity by

Sulphat of copper, and a great many other sulphats,
Phosphat of foda,
Borax.

23. Nitrats of ammonia and mercury. This triple salt may be formed by pouring ammonia into a solution of mercury,

Nitrats.

* Fourcroy, 680
Nitrats of manganese.† Scheele on Manganese, 681
Nitrats of cobalt, 682
Of nickel,‡ Bergman, ii. 268.
§ 683
Of lead,§ Bergman, 694
Of tin,685
Of copper,

|| Sage.

686
Of bismuth,687
Of antimony,688
Of arsenic,689
Of mercury,690
Of ammonia and mercury,

Muriats. of nitrat of mercury. If only enough of ammonia to saturate the acid be used, the triple salt precipitates in the form of a white powder; but with an excess of ammonia it remains dissolved, and forms by evaporation very bright polyhedral crystals.

It has a very sharp taste. It is soluble in 1200 parts of water at the temperature of 55°. Hot water separates a little ammonia, which renders it still more insoluble. It turns vegetable blues green. Muriatic acid dissolves it.

According to Fourcroy's analysis, it is composed of 68,20 parts of oxide of mercury, 16 of ammonia, and 15,80 of nitric acid and water.

When distilled it yields ammonia, azotic gas, oxygen gas, yellow oxide of mercury, and pure mercury*.

* Fourcroy, Ann. de Chim. xiv. 37. 24. Nitrat of silver. This salt may be formed by dissolving silver in nitric acid.

691 Nitrat of silver, It forms flat transparent crystals composed of needles. It is exceedingly caustic. When melted it forms a grey mass called *lapis infernalis*, from its great corrosiveness.

It is very soluble in water. It is not altered by exposure to the air. Light decomposes it.

By compound affinity it is decomposed by
The sulphats,
The muriats.

692 Nitrat of uranium, 25. Nitrat of uranium. This salt was first formed by Klaproth. Its crystals are hexagonal plates of a greenish yellow colour. The largest were ¼ths of an inch in length and ¼th in breadth †.

† Klaproth, Journ. de Phys. xxxvii. 158. 26. Nitrat of titanium. It is capable of crystallizing.

693 Titanium, 27. Nitrat of tellurium. The solution of tellurium in nitric acid is transparent and colourless. When concentrated, it produces in time small white light crystals in the form of needles, which exhibit a dendritic aggregation ‡.

† Klaproth, Phil. Mag. i. 30.

SECT. IV. Of Nitrites.

THE salts which the nitrous acid forms with alkalies, earths, and metallic oxides, are denominated *nitrites*. Very few of them have been examined; we shall not therefore attempt a description of them.

SECT. V. Of Muriats.

SALTS into which the muriatic acid enters are called *muriats*.

695 Muriat of potafs, 1. Muriat of potafs. This salt was formerly called *febrifuge* or *digestive salt* of Sylvius, and *regenerated sea salt*. Its crystals are cubes, but rather irregular.

§ Kirwan. It has a disagreeable bitter taste. Its specific gravity is 1,836 †.

¶ Bergman. It is soluble in three times its weight of water at the temperature of 60°, and in double its weight of boiling water †.

It is composed, according to Bergman, of 31 parts of acid, 61 of potafs, and 8 of water. Kirwan has found it to contain 36 of acid, 46 of alkali, and 18 of water ‡.

† Kirwan's Mineral. ii. 30.

It suffers little alteration from exposure to the air.

When exposed to heat, it first decrepitates, then melts, and at last is volatilized, but without decomposition.

The following salts decompose it by compound affinity:

Sulphat of foda,	Nitrat of ammonia,
— — — ammonia,	— — — magnesia,
— — — alumina,	— — — alumina,
Nitrat of foda,	— — — lead.
— — — lime,	

2. Muriat of foda, common or sea salt. This salt has been known, and in common use, from the earliest ages. It is sometimes called also *sal gem*.

Muriats.
696
Muriat of foda.
* Kirwan.

Its crystals are cubes, but they often assume other forms. Its specific gravity is 2,120*.

Its taste is universally known, and is what is strictly speaking denominated *salt*.

It is soluble in 2¼ times its weight of water at the temperature of 60°, and in 2½ its weight of boiling water †.

† Bergman.

According to Bergman, it is composed of 52 parts of acid, 42 of alkali, and 6 of water. According to the late experiments of Mr Kirwan, of 40 parts of acid, 35 of alkali, and 25 of water.

It is not affected by exposure to the air. It ought to be observed, however, that the muriat of foda in common use contains, besides other impurities, a quantity of muriat of magnesia, which renders it deliquescent.

When heated it decrepitates. Heat volatilizes, but does not decompose it.

The following salts decompose it by compound affinity:

Sulphat of ammonia,	Nitrat of silver §,
— — — alumina,	Acetite of barytes,
— — — potafs*,	Pyrolignite of barytes ,
— — — iron †,	— — — lead ,
Nitrat of ammonia,	Carbonat of potafs (a),
— — — magnesia,	Alum (b),
— — — alumina,	Red oxide of lead (c).
— — — lead ‡,	

* Fuchs, Ann. de Chim. vi. 29.
† Bullen, ibid. xi. 320.
‡ Morveau, § Bergman, || Morveau, Ann. de Chim. xix. 109.
(a) Bergman, (b) Crell, Ann. de Chim. xxvi. 217.
(c) Scheele, 697
How decomposed by red oxide of lead.
* Ann. de Chim. xiv. 15.

That the red oxide of lead decomposes this salt is a well known fact, and it has been considered as contrary to the laws of affinity. Mr Hassenfratz endeavoured to account for it by supposing that the oxide is combined with carbonic acid, and that therefore it is a case of compound affinity. Mr Curaudau has proved that carbonic acid, instead of promoting, impedes the decomposition; and that, in fact, carbonat of lead is incapable of decomposing muriat of foda. He concludes, therefore, that the phenomenon cannot be accounted for by the commonly received laws of affinity* We cannot, however, think that the phenomenon is so unaccountable as Mr Curaudau supposes; for muriatic acid is capable of decomposing the red oxide of lead, of combining with part of its oxygen, and of being converted into oxy-muriatic acid. Now if oxy-muriatic and nitro-muriatic acids be merely the same substance in a different form, as there is the strongest reason for supposing, the white oxide of lead has a stronger affinity for it than foda has, and ought therefore to decompose it.

3. Muriat of ammonia, or sal ammoniac. This salt was known to the ancients, and was called by them *sal ammoniac*, because it was found in great quantities near the temple of Jupiter Ammon in Africa †.

698 Muriat of ammonia.

It assumes the form of plumose crystals. The individual crystals are long hexahedral pyramids. Its specific gravity is 1,420 ‡.

† Pliny, lib. xxxi. c. 7. See *Sal Ammoniac*, Encyc. ‡ Kirwan.

It has an acrid, poignant, urinous taste. It dissolves in about three times its weight of water at the temperature of 60°, and in a much smaller quantity of boiling water.

It is composed, according to Kirwan, of 35 parts of acid, 30 of alkali, and 45 of water §.

In its common form (which is an opaque mass) it is not affected by the air, but its crystals are liable to deliquesce.

§ Kirwan's Mineral. ii. 34.

Heat volatilizes without decomposing it.
The following salts decompose it by compound affinity :

Sulphat of alumina,	Acetite of magnesia,
Nitrat of soda,	———— alumina,
———— lead,	———— lead,
Acetite of barytes,	Carbonat of barytes,
———— potafs,	———— potafs,
———— soda,	———— magnesia (y)
———— lime,	

When this salt is sublimed with gold leaf, there is found in the neck of the retort an amethyst coloured matter, bordering on purple, soluble in water, and forming a purple solution. When filtered there remains behind a purple powder. This salt seems from this to be capable of oxidating gold*.

* *Storr, Crell's New Discoveries, &c. Part ii. p. 41.*
699
Muriat of barytes,

4. Muriat of barytes. This salt was first described by Bergman, but it has been most particularly attended to by Dr Crawford.

It affords oblong square crystals.

It has an unpleasant astringent taste.

It is not very soluble in water. It is soluble in alcohol.

It is not altered by exposure to the air, nor does heat in all probability decompose it.

Dr Crawford wrote a treatise on it in 1790, in which he recommended its use internally for scrofulous complaints. Care ought to be taken not to give it in too large quantities, as, like the other compounds of barytes, it is poisonous.

The following salts decompose it by compound affinity (z) :

Sulphat of soda	Nitrat of lime,
———— ammonia,	———— ammonia,
———— magnesia,	———— magnesia,
———— alumina,	———— alumina,
Nitrat of soda,	Phosphat of lime †.

† *Dr Pearson.*
700
Muriat of ammonia and barytes,
‡ *Ann. de Chim. iv. 8.*
701
Muriat of lime,

5. Muriat of ammonia and barytes. This triple salt was first discovered by Fourcroy. It may be formed by pouring a carbonat of ammonia into a solution of muriat of barytes. It is easily decomposed by heat, but none of the alkalies nor their carbonats are capable of altering it †.

6. Muriat of lime. This salt was formerly called *fixed ammoniac*, because it was commonly obtained by decomposing sal ammoniac by means of lime.

Its crystals are four-sided striated prisms, terminated by a very sharp pyramid; but it is not easily crystallized.

Its taste is very bitter.

It is soluble in about 1½ parts of cold water, and in less than its own weight of boiling water. Alcohol dissolves its own weight of it.

According to Bergman, it is composed of 31 parts of acid, 44 of lime, and 25 of water. According to Kirwan, 100 parts of lime require for saturation 86 parts of muriatic acid.

(y) Only at the common temperature. At a high temperature carbonat of ammonia decomposes muriat of magnesia. See *Westrumb, Ann. de Chim. ii. 118.*

(z) Bergman affirmed, that this salt decomposed all the sulphats, and proposed it therefore as a certain means of discovering the presence of sulphuric acid, however combined in any solution; for the sulphat of barytes is almost entirely insoluble in water. But Mr Piffis has observed, that it does not decompose sulphat of lime nor of potafs. See *Ann. de Chim. xv. 317.*

It very speedily deliquesces when exposed to the air. Muriats.
By heat it melts into a very hard vitreous substance.

The following salts decompose it by compound affinity :

Sulphat of soda,	Carbonat of potafs,
———— ammonia,	———— soda,
———— magnesia,	———— ammonia*, * <i>Bergman.</i>
———— alumina,	———— barytes,
Nitrat of soda,	———— magnesia,
———— ammonia,	———— alumina,
———— magnesia,	Acetite of barytes,
———— alumina,	———— potafs,
	———— soda.

7. Muriat of stontites. This salt was first formed by Dr Hope. Its crystals are very long, slender, hexagonal prisms. It has a peculiar, sharp, penetrating taste.

Three parts of these crystals are soluble in two parts of water at the temperature of 60°. Boiling water dissolves any quantity of them whatever.

They contain 42 per cent. of water of crystallization.

They suffer no change when exposed to the air except it be very moist; in which case they deliquesce.

When heated, they first undergo the watery fusion, and are then reduced to a white powder. A very violent heat decomposes this salt.

Muriatic acid precipitates this salt from its solution in water. That acid, therefore, has a stronger affinity for water than the salt has †.

8. Muriat of magnesia. This salt abounds in sea water.

It is not easily crystallized. Bergman's method was to evaporate it by a considerable heat to the proper degree of concentration, and then to expose it to a sudden cold. By this method he obtained it in small needles †.

It has a very bitter taste. It is soluble in its own weight of water †, and in five parts of alcohol †.

A saturated solution of it quickly forms a jelly; on which if hot water be poured spongy masses are formed not even soluble in muriatic acid †.

It is composed, according to Bergman, of 34 parts of acid, 41 of earth, and 25 of water. According to Kirwan, 100 parts of magnesia require for saturation 104,275 of acid*.

It deliquesces very speedily when exposed to the air.

A strong heat decomposes it. When dried in a high temperature, it is very caustic †.

The following substances decompose it by compound affinity :

Sulphat of soda,	Acetite of potafs;
———— ammonia,	———— soda,
———— alumina,	———— silver †.
Nitrat of ammonia,	

Carbonat

702

† *Hope, Transf. Edin. iv. 12.*

703
Muriat of magnesia,

† *Bergman, ii. 383.*

§ *Fourcroy, Bergman, ii. 383.*

¶ *Bergman, ibid.*

* *Irish, Transf. iv.*

† *Westrumb, Ann. de Chim. ii. 135.*

† *Bergman.*

Muriats. **Carbonat of barytes,** **Carbonat of soda**
 ————— potafs, ————— ammonia (γ).
 704 Muriat of ammonia and magnesia. This triple salt was first mentioned, we believe, by Bergman. It may be formed by pouring ammonia into a solution of muriat of magnesia. Part of the magnesia is precipitated, but great part of it remains dissolved, and combined with the acid and the ammonia. This triple salt is composed, according to Fourcroy, of 73 parts of muriat of magnesia and 27 of muriat of ammonia *.

* *Ann. de Chim. iv. 222.*
 705 Muriat of alumina. This salt crystallizes with difficulty. It has an astringent taste. Its solution is gelatinous, and cannot be filtrated without much dilution in water. It is deliquescent. When evaporated to dryness, it forms a gummy mass: in a strong heat it is decomposed.

The following salts decompose it by compound affinity:

Nitrat of ammonia,	Acetite of magnesia,
Acetite of barytes,	Carbonat of barytes,
———— potafs,	———— potafs,
———— soda,	———— soda,
———— lime,	———— ammonia.

706 Muriat of jargonina. This salt is easily formed by pouring muriatic acid on newly precipitated jargonina. It is colourless; its taste is very astringent: by evaporation it furnishes small transparent crystals in needles, which lose their transparency in the air. Muriat of jargonina is very soluble in water and in alcohol; to the flame of which it does not communicate any particular colour. Heat decomposes it; and it is decomposed likewise by the saliva when taken into the mouth.

When muriat of jargonina contains a little silica, it forms cubic crystals without consistence, and resembling a jelly. These crystals, when exposed to the air, gradually lose their transparency, and diminish in volume, and there are formed in the middle of the salt white silky needle-shaped crystals.

Muriat of jargonina is decomposed by sulphuric acid; part of the sulphat precipitates, and part remains dissolved in the muriatic acid. When this acid is driven off by heat, the remainder of the sulphat is gradually deposited: if the evaporation be stopped before the mass be reduced to dryness, it forms a kind of jelly when cold. It is also decomposed by the phosphoric, citric, tartarous, oxalic, and saccholactic acids, which form with jargonina insoluble compounds that precipitate in white flakes.

The gallic acid poured into muriat of jargonina produces a white precipitate; but a green, bordering on grey, if the jargonina contain iron; and this last precipitate becomes, when dry, of a bright black colour, and resembles China ink. The liquid preserves a greenish colour; new portions of gallic acid produce no farther precipitation; but carbonat of ammonia separates in great abundance a flaky matter of a purplish colour, not unlike that of the leys of wine. From these experiments it follows, that gallic acid has a greater affinity for jargonina than muriatic acid has; and that the galats of jargonina and iron are soluble in muriatic acid.

Carbonat of potafs decomposes muriat of jargonina,

and part of the carbonic acid combines with the earth, and renders it easily soluble in acids though dried.

Carbonat of ammonia occasions a precipitate, which is mostly dissolved by adding more carbonat.

Prussiat of mercury produces an abundant precipitate, which is soluble in muriatic acid; and which consequently is not muriat of mercury.

A plate of zinc, introduced into a solution of muriat of jargonina, occasions a slight effervescence; the liquor becomes milky, and in a few days becomes a white semitransparent jelly.

Alumina decomposes muriat of jargonina with the assistance of a slight heat: the alumina dissolves, the liquor becomes milky, and assumes the form of a jelly. When the muriat contains iron, it remains in the solution, and the precipitated jargonina is quite pure. Here, then, is a method of freeing jargonina from iron *.

12. Muriat of iron.—Muriatic acid forms with the green oxide of iron a salt which crystallizes in flat needles. When exposed to the air, they deliquesce, and the green oxide attracts oxygen, and is gradually converted into a brown oxide. Heat decomposes this iron salt.

13. Muriat of zinc.—This salt, procured by dissolving zinc or its oxide in muriatic acid, does not crystallize. Its solution is colourless. When heated, it becomes of a blackish brown. By distillation, a part of the acid is separated, and muriat of zinc remains behind of a milk-white colour, solid, and formed of small radiated needles. It attracts moisture in the air.

14. Muriat of manganese.—Muriatic acid dissolves the white oxide of manganese. Its solution affords by evaporation angular shining crystals †: They are deliquescent and soluble in alcohol ‡.

14. Muriat of cobalt.—The solution of oxide of cobalt in muriatic acid is of a pale red, except it be contaminated with nickel or iron, when it is greenish. It crystallizes in small needles, which are very deliquescent. Heat decomposes it.

16. Muriat of nickel.—This salt is deliquescent, and loses its acid when exposed to the air §.

17. Muriat of lead.—Muriatic acid combines with oxide of lead easily enough; but this salt is more readily procured by pouring muriatic acid into a solution of nitrat of lead; the muriat immediately precipitates in the form of a white powder. It is soluble in 30 times its weight of boiling water; and the solution yields by evaporation small, slender, brilliant needles in bundles.

It is somewhat deliquescent. When exposed to heat, it melts into a brown mass, formerly called *corneous lead*.

It is decomposed by compound affinity by
 Sulphat of silver ||,
 Carbonat of soda.

18. Muriat of tin.—This salt may be formed by dissolving tin in hot muriatic acid. By evaporation it affords needle-shaped crystals, which are deliquescent.

This salt has a strong affinity for oxygen. It decomposes oxy-muriatic, nitric, sulphurous, arsenic, molybdic, and tungstic acids, the red oxide of mercury, black oxide of manganese, oxide of antimony, zinc, silver,

Muriat e.

* *Vauquelin, Ann. de Chim. xxii. 201.*

707 Muriat of

708 Muriat of zinc,

709 Muriat of manganese, † *Scheele on Manganese.* ‡ *Kirwan's Mineral. ii. 37.*

710 Cobalt,

711 Nickel, § *Bergman, ii. 268.*

712 Lead,

|| *Bergman, 713 Tin,*

(γ) Only at a high temperature. See *Muriat of Ammonia*.

Muriats. ver, and gold; and by that means is converted into oxy-muriat of tin. It even absorbs oxygen when exposed to the air *. These compositions are doubtless produced by *disposing affinity*.

* *Pelletier, Ann. de Chim. xii. 225.*
19. Muriat of copper.—This salt may be formed by dissolving copper or its oxide in muriatic acid.

714
Muriat of copper, Its crystals are prismatic. It is of a beautiful grass green colour. It has a very astringent and caustic taste. It deliquesces when exposed to the air. A moderate heat is sufficient to melt it; and when cooled it congeals into a mass. It requires a strong heat to volatilize it.

† *Bergman, 715*
Muriat of bismuth, It is decomposed by nitrat of silver †.
716
Antimony, 20. Muriat of bismuth.—This salt crystallizes with difficulty. By sublimation it forms a soft fusible substance, formerly called *butter of bismuth*.

717
Arsenic, 21. Muriat of antimony.—This salt is found native. It crystallizes in prisms. When heated it evaporates.

† *Bergman, ii. 293.*
718
Mercury, 22. Muriat of arsenic.—This salt crystallizes; it is very volatile, and not very soluble, in water †.

23. Muriat of mercury.—This salt may be prepared by pouring diluted muriatic acid into a diluted solution of nitrat of mercury: the muriat of mercury is immediately precipitated in the form of a white powder. Common salt may be used instead of muriatic acid. This salt was formerly called *white mercurial precipitate* and *calomel*.

It crystallizes; but the form of the crystals, which are very small, has not been determined.

It has little taste. It is almost insoluble in water. It is used as a medicine.

§ *Bergman, 719*
Muriat of ammonia and mercury, It is decomposed by sulphat of ammonia §.

24. Muriat of ammonia and mercury.—This triple salt was first discovered by Fourcroy. It may be formed by pouring ammonia into a solution of corrosive muriat of mercury. It has the appearance of a white powder. Its taste is at first earthy, afterwards metallic. It is nearly insoluble in water. According to Fourcroy's analysis, it is composed of 81 parts of oxide of mercury, 16 of muriatic acid, and 3 of ammonia.

Heat decomposes it; producing ammonia, azotic gas, and muriat of mercury.

¶ *Fourcroy, Ann. de Chim. xiv. 47.*
720
Muriat of silver, Sulphuric, nitric, and muriatic acids decompose it ¶.

25. Muriat of silver.—This salt may be formed by dissolving oxide of silver in muriatic acid, or, which is better, by pouring muriatic acid into nitrat of silver; muriat of silver immediately precipitates. It is very little soluble in water; according to Monnet, one part of it requires 3072 parts of water.

When exposed to a small heat, it melts into a grey semitransparent mass, not unlike horn; hence it was formerly called *luna cornea*. A long continued heat decomposes it. This salt is very caustic: it is employed as an escharotic under the name of *lunar caustic*.

721
Muriat of titanium, 26. Muriat of titanium has been formed by Mr Klapproth.

SECT. VI. *Of Oxy-muriats.*

THOSE salts, into which the oxy-muriatic acid enters as an ingredient, are called *oxy-muriats*. As we consider the nitro-muriatic acid to be precisely the same with the oxy-muriatic, its combinations of course must receive the same name.

1. Oxy-muriat of potash.—This singular salt was discovered by Mr Berthollet in 1786. It may be formed by saturating a solution of potash with oxy-muriatic acid gas. By evaporating this solution in the dark, Oxy-muriat of potash is first obtained: When it is separated, and the liquor allowed to cool, oxy-muriat of potash crystallizes.

Its crystals are rhomboids, of a silvery brilliancy. It has an insipid cooling taste, resembling that of nitre.

It is soluble in 17 parts of water at the temperature of 60, and in 2½ parts of boiling water *. It does not deliquesce in the air; but light converts it into common muriat by separating oxygen. When heated, it melts, and gives out oxygen gas; and this is the best method hitherto discovered of obtaining that gas in a state of purity. According to Mr Hoyle, it contains about half its weight of concrete oxygen †.

When mixed with charcoal, iron, and many other combustibles, and heated, it detonates with astonishing violence. This property induced the French chemists to propose it as a substitute for nitre in the preparation of gunpowder. The attempt was made at Essons in 1788; but no sooner had the workmen begun to triturate the mixture of charcoal, sulphur, and oxy-muriat, than it exploded with violence, and proved fatal to Mr Letors and Mademoiselle Chevrard. The force of this gunpowder when it is prepared is much greater than that of the common sort of powder; but the danger of preparing it, and even of using it after it is prepared, is so great, that it can hardly ever be substituted with advantage for common gunpowder.

Fourcroy and Vanquelin ascertained by experiment, that this salt exploded when triturated with sulphur, charcoal, antimony, arsenic, cinnabar, sugar, gums, oils, alcohol, ether, and sulphuret of iron. When these substances were mixed, and struck with a hammer, the explosion took place. The theory of these explosions was first pointed out by Mr Berthollet. The oxygen of the oxy-muriatic acid combines with the combustible, and at the same time lets go a quantity of caloric; and trituration or percussion acts merely by bringing the particles which combine within the sphere of each others attraction.

2. Oxy-muriat of soda. This salt was discovered at the same time by Mr Berthollet. Its properties are the same with the last, except that it is too deliquescent to be used.

3. Oxy-muriat of ammonia.—This combination is impossible. The oxy-muriatic acid and ammonia decompose each other.

4. Oxy-muriat of barytes. } These salts were discovered by Berthollet
5. ——— lime. } also. They all possess
6. ——— magnesia. } the property of detonating with combustibles, and of being reduced by that means to the state of common muriats. Mr Tennant has lately proposed the oxy-muriat of lime as a substitute for the other substances formerly used in the new mode of bleaching; particularly for bleaching printed cottons: And, as far as we can learn, it answers the purpose remarkably well (z).

7. Oxy-muriat of mercury.—This salt was formerly called *corrosive sublimate*, and afterwards *corrosive muriat* of mercury.

(z) We have been informed, that this salt had been used by bleachers in Scotland some years before Mr Tennant proposed it.

Oxy-muriatic. of mercury. Berthollet first pointed out the nature of its composition.

This salt was mentioned by Rhafes in the 10th century; and it seems to have been known in the east at a much earlier period (A). The methods of preparing it used by the older chemists were numerous, complicated, and generally concealed as secrets. We shall not attempt, therefore, to give any account of them; and the methods used by later chemists have been described at considerable length in the article CHEMISTRY (*Encycl.* n° 815.)

It may be prepared by dissolving mercury in a sufficient quantity of oxy-muriatic acid, or by dissolving red oxide of mercury in common muriatic acid.

When carefully crystallized, this salt assumes the form of cubes or oblique parallelepipeds, or rather quadrangular prisms, with sides alternately narrower, and terminated by two inclined planes meeting together.

It has an exceedingly disagreeable metallic taste.

It is soluble in 19 times its weight of water at the temperature of 50°*. Boiling water, according to Macquer, dissolves half its weight of it. Alcohol, at the temperature of 70°, dissolves $\frac{3}{4}$ ths of its weight of this salt †.

It does not attract moisture from the air.

It is soluble in sulphuric, nitric, and muriatic acids.

When triturated with $\frac{3}{4}$ ths of its weight of mercury and a little water, and then sublimed, it forms a white insipid salt, called formerly *calomel* or *sweet mercury*: This, as Scheele has proved, is precisely the same with common muriat of mercury.

The theory of these two preparations is now pretty obvious. The experiments of Adet and Pelletier have shewn, that oxy-muriatic acid may be obtained from corrosive muriat of mercury †. We may conclude, therefore, with confidence, that the salt is an oxy-muriat. It cannot be prepared by means of common muriatic acid, except with red oxide of mercury, or some other substance from which it may absorb oxygen. When pure mercury is added to oxy-muriat, it seizes the oxygen from the oxy-muriat, and the whole is converted into common muriat.

It is decomposed by

Tartar,

Moist metals.

726
Oxy-muriat of tin,

8. Oxy-muriat of tin. When an amalgam of tin is triturated with its own weight of corrosive muriat of mercury, and the mixture is distilled in a glass retort by means of a very gentle heat, there passes over a thick white smoke, which condenses into a colourless liquor that emits copious fumes, and has been called, in consequence, *smoking liquor of Libavius*. This liquor was examined by Mr Adet. He found, that when about $\frac{1}{2}$ d part of water was added to this liquor, it ceased to fume, and assumed a crystalline form; that then it might even be made red hot without subliming. It therefore owes its volatility to want of water, or rather to a strong attraction for water. He found that this substance was capable of dissolving, and therefore of oxidating more tin, without the emission of any hydrogen, and consequently without the decomposition of

water; he concluded from this, that it was composed of Phosphats. oxy-muriatic acid and tin*. This has been completely proved by Mr Pelletier, who found that when oxide of tin was combined with oxy-muriatic acid, it formed a compound precisely the same with the smoking liquor of Libavius †.

This salt may be prepared, as Pelletier has proved, by dissolving tin in muriatic acid, and then saturating it with oxy-muriatic acid gas.

It is used in dyeing.

727
9. Oxy-muriat of iron. This salt is deliquescent; Oxy-muriat of iron. colourless; of a pure bitter taste, without any of the sweet astringency of the common salts of iron †.

Few of the other oxy-muriats have been hitherto examined with attention: Many of the metals, indeed, have been dissolved in aqua-regia; but in most of these solutions the salt produced is a common muriat. The nitric acid supplies oxygen, and the muriatic acid dissolves the oxide.

SECT. VII. Of Phosphats.

THOSE salts, into which phosphoric acid enters as an ingredient, are called *phosphats*. This class of salts was first discovered by Margraf.

1. Phosphat of potash. This salt crystallizes in short tetrahedral prisms, terminated by quadrangular pyramids.

It is very soluble in cold water, and still more so in hot water.

It decrepitates on ignited coals like common salt. When a very strong heat is applied, it melts into an opaque vitreous mass, still soluble in water.

The following salts decompose it by compound affinity:

Sulphat of lime, Muriat of mercury,
Nitrat of mercury, Acetite of lead.

2. Phosphat of soda.—Dr Pearson, who first formed this salt, gives the following process for preparing it: *729*
of soda,

Dissolve in a long-necked matrass 1400 grains of crystallized carbonat of soda in 2100 grains of water at the temperature of 150°. Add gradually 500 grains of phosphoric acid of the specific gravity 1,85. Boil the liquor for some minutes; and while it is boiling hot, filtrate it, and pour it into a shallow vessel. Let it remain in a cool place, and crystals will continue to form for several days. From the above quantities of materials he has obtained from 1450 to 1550 grains of crystals.

Its crystals are rhomboidal prisms, of which the acute angles are 60°, and the obtuse angles 120°, terminated by a three-sided pyramid.

Its taste is almost the same with that of common salt.

It is soluble in water. When exposed to the air it effloresces.

This salt has been introduced into medicine as a purgative, and on account of its pleasant taste has of late been much used. It is usually taken in broth, which it is employed to season instead of common salt.

Hellot remarked a particular salt in urine, different from those that had usually been observed, in 1737. Haupt described it in 1740 under the name of *sal mirabile*

(A) If we listen to Junker, the ancients applied the name *mercurium* to this salt; mercury they called *argenterum vivum*.

Phosphat's *rabile perlatum*, or *wonderful perlated salt*. It was called *perlated* from the grey, opaque, pearl-like colour which it assumed when melted by the blow-pipe. Margraf described it in 1745, and found it would not yield phosphorus when treated with charcoal, as the other salts of urine did. Rouelle the Younger analysed it in 1776, and concluded from his experiments that it was a compound of phosphoric acid and soda; but Mr Proust, being unable to obtain phosphorus from it, concluded, that it did not contain phosphoric acid, but another acid analogous to the boracic. To this substance, which Mr Proust actually obtained, Bergman gave the name of *perlated acid*, and Morveau afterwards called it *ouretic acid*. But Mr Klaproth soon afterwards analysed it, and proved that it consisted of soda supersaturated with phosphoric acid. Scheele soon after made the same discovery. This acid of Mr Proust, then, is merely phosphat of soda combined with phosphoric acid, or *acidulous phosphat of soda*.

730
Phosphat of ammonia,
3. Phosphat of ammonia.—This salt forms oblong-pointed crystals, or, as Mr Lavoisier affirms, crystals resembling those of alum.

It is soluble in water. Heat evaporates it so easily, that it is difficult to obtain it in crystals except by adding an excess of alkali.

Microcosmic salt, or salt of urine, is merely a mixture of these two last described salts.

731
Of barytes,
* *Morveau.*
4. Phosphat of barytes.—This salt is insoluble in water*.

732
Of lime,
5. Phosphat of lime.—This salt is tasteless, and almost perfectly insoluble in water. It forms the basis of bones, and is therefore often called *earth of bones*. Wenzel observed it crystallize when held in solution by phosphoric acid.

It is decomposed by sulphat of ammonia †.

Carbonat of potash ‡,

— — — — — soda §.

† *Dellekamp Ann. de Chim. vi.*
‡ *Bergman § Id.*
6. Phosphat of strontites.—This salt was first formed by Dr Hope. It is a white powder soluble in 1920 parts of boiling water ||.

733
Of iron
|| *Dr Hope Trans. Edin. iv. 16.*
7. Phosphat of magnesia.—This salt does not crystallize except with excess of acid, and then the crystals are very small. Somewhat longer crystals may be formed by dropping phosphoric acid into acetate of magnesia. It most commonly forms by evaporation a gummy mass. It is soluble in alcohol ¶.

It is insoluble in nitric acid. It melts by a strong heat into a porcelain-like substance*.

734
Of magnesia,
¶ *Bergman, § Id.*
8. Phosphat of alumina.—This is a saline powder, insoluble in water. Dissolved in phosphoric acid, it yields a gritty powder, and a gummy solution, which by heat is converted into a transparent glass.

736
Of iron,
9. Phosphat of iron.—This salt is merely a dry adhesive mass, insoluble in water, but soluble in acids. With excess of acid, it forms crystals which do not deliquesce, and by heat are converted into a garnet-coloured glass †.

† *Id.*
737
Of zinc,
10. Phosphat of zinc.—It does not crystallize, but when evaporated becomes a gummy mass, which may be melted into a transparent glass ‡.

‡ *Id.*
738
Of manganese,
11. Phosphat of manganese.—The solution of the oxide of manganese in phosphoric acid is reddish, but becomes white on exposure to the air.

739
Of nickel,
§ *Bergman, § Id.*
12. Phosphat of nickel.—It is greenish, and does not crystallize §.

13. Phosphat of arsenic.—It crystallizes in small grains hardly soluble in water*.

14. Phosphat of uranium.—First formed by Klaproth. It does not crystallize, but assumes the appearance of yellowish white flakes, difficultly soluble in water. **740** *Bergman, § Id.*

15. Phosphat of antimony and lime.—Dr Pearson has discovered, that the well known medicine called *James's Powder* is a triple salt, composed of phosphoric acid, oxide of antimony, and lime. It is very insoluble in water. **741** *Of uranium, James's powder.*

The remaining phosphats are scarcely known.

SECT. VIII. Of Borats.

THE compounds into which the boracic acid enters are called *borats*.

1. Borat of potash.—This salt, formed by combining boracic acid and potash, is very little known. Baron Borat first formed it. Borat of potash crystallizes, is soluble in water, and may be melted into a vitreous mass, soluble in water. **743** *Of arsenic, Bergman, § Id.*

2. Borat of soda or borax.—This salt is brought from the East Indies in an impure state under the name of *tinkal*. When purified in Europe, it takes the name of *borax*. **744** *Of soda,*

Its crystals are hexangular prisms, of which two sides are much broader than the remainder, terminated by triangular pyramids. It is of a white colour. Its specific gravity is 1,740.

Its taste is styptic and alkaline.

It is soluble in 18 times its weight of water of the temperature of 60°, and 6 times its weight of boiling water.

It is composed, according to Bergman, of 17 parts of soda, 39 of acid, and 44 of water.

When exposed to the air, it effloresces slowly and slightly.

When heated, it swells, loses about four-tenths of its weight, becomes rosy, and then assumes the form of a light, porous, and very friable mass, known by the name of *calcined borax*; it then melts into a transparent glass, still soluble in water.

By compound affinity it is decomposed by

Nitrat of mercury †.

† *Bergman.*

When two pieces of borax are struck together in the dark, a flash of light is emitted ‡.

Borax has the property of facilitating the fusion of a great number of bodies. This property renders it useful in glass-making, in assaying ores, and in soldering metals. † *Accum, Nicholson's Journal, ii. 28.*

Borax turns syrup of violets green; it appears therefore to be supersaturated with alkali.

The real borat of soda, or the salt in which boracic acid and soda saturate each other, has not yet been examined with attention. According to Dr Withering, soda requires twice its weight of boracic acid to saturate it.

3. Borat of ammonia.—This salt has been examined only by Mr Fourcroy. **745** *Of ammonia,*

Its crystals are polyhedral pyramids.

It has a poignant urinous taste, and turns syrup of violets green. It dissolves readily enough in water. When exposed to the air, it gradually loses its crystalline form and becomes brown §. *Fourcroy's Chemistry, Part II.*

4. Borat ch. 4.

Borats.
 746
 Of lime,
 747
 Of iron-
 tites,
 * Hope,
 Trans. Edin.
 iv. 17.
 748
 Of magne-
 sia,
 † Bergman,
 ii. 386.
 749
 Of alumi-
 na,
 750
 Of iron,
 751
 Of zinc,
 † Reufs.
 752
 Cobalt,
 § Id.
 753
 Nickel,
 ‖ Bergman.
 754
 Lead,
 ¶ Reufs.
 755
 Tin,
 756
 Copper,
 * Bergman.
 757
 Bismuth,
 † Wenzel.
 758
 Arsenic,
 ‡ Reufs.

4. Borat of barytes.—Unknown.
 5. Borat of lime.—It is difficultly soluble in water, and did not crystallize with Beaumé.
 6. Borat of stontites.—This salt was first formed by Dr Hope.—It is a white powder, soluble in about 130 parts of boiling water. The solution turns the syrup of violets green *.
 7. Borat of magnesia.—It assumes the appearance of small irregular crystals. It is soluble in acetous and formic acids. Alcohol decomposes it. It melts easily in the fire without being decomposed †.
 8. Borat of alumina.—It does not crystallize, and is scarcely soluble in water.
 9. Borat of iron.—Its crystals are of a yellow colour, but the salt has never been examined with attention.
 10. Borat of zinc.—This salt does not appear to be capable of crystallizing. By heat, it melts into a light green insoluble slag ‡.
 11. Borat of cobalt.—When oxide of cobalt is melted with boracic acid, a bluish grey slag is produced. This, by lixiviation and evaporation, yields crystals of a reddish white colour and ramified form §.
 12. Borat of nickel.—A saline substance difficultly soluble ||.
 13. Borat of lead.—When boracic acid and red oxide of lead are melted together, the product is a fine greenish yellow, transparent, hard, insoluble glass ¶.
 14. Borat of tin.—When equal parts of boracic acid and tin filings are melted together, the product dissolved in water yields by evaporation transparent white polygonous crystals.
 15. Borat of copper.—When borax is poured into a solution of sulphat of copper, borat of copper is precipitated in the form of a pale light green jelly, which when dried is with great difficulty soluble in water. It easily melts into a dark red vitreous substance *. According to Palm, by long trituration of filings of copper and boracic acid in water, and then digesting the mixture, it dissolves, and crystals may be obtained from it.
 16. Borat of bismuth.—A white powder, which melts into a white transparent permanent glass †.
 17. Borat of arsenic.—White oxide of arsenic and boracic acid form a salt soluble in water and crystallizable ‡.

SECT. IX. Of Fluats.

THOSE salts into which fluoric acid enters are called *fluats*. They were first formed by Scheele.

759
 Fluat of potafs,
 § Scheele on Fluor.
 760
 Soda,
 ‖ Ibid.
 761
 Ammonia,
 ¶ Wiegleb.
 762
 Barytes,
 * Bergman.
 763
 Lime,

1. Fluat of potafs. It forms a gelatinous mass almost without taste. It dissolves readily in water. When exposed to the fire it melts without any ebullition §.
 2. Fluat of soda. This salt resembles exactly the fluat of potafs ||.
 3. Fluat of ammonia. It crystallizes in small prisms. It is deliquescent, and is partly decomposed by heat ¶. It is decomposed by
 Nitrat of mercury,
 ———— silver,
 ———— lead.
 4. Fluat of barytes. A powder which requires a large quantity of water to dissolve it *.
 5. Fluat of lime. This salt abounds in nature. It is known by the name of fluor spar. It crystallizes most commonly in the form of cubes.

It is tasteless and nearly insoluble in water. It is not altered by the air. Its specific gravity is about 3,1.

Fluats.

When exposed to a sudden heat it decrepitates. A very violent heat melts it into a white opaque mass.

When reduced to powder and heated it becomes phosphorescent; but it loses this quality altogether if it be heated red hot.

6. Fluat of stontites. This salt was formed by Dr Hope: but its properties have not been examined.

7. Fluat of magnesia.—It is not soluble in water except there be an excess of acid. In that case, by spontaneous evaporation, it forms hexagonal prisms, terminated by a low pyramid composed of three rhomboidal sides.

These crystals are hardly soluble in water. Alcohol dissolves a small portion of them. Heat does not decompose them *.

8. Fluat of alumina. A saline mass; which is sweetish, clammy, and gelatinous.

9. Fluat of silica. Little is known concerning this singular combination, except that it can exist in a gaseous form, and that it deposites silica in crystals after a certain time.

10. Fluat of silica and potafs or soda. This triple salt may be formed by pouring fixed alkali into a solution of fluat of silica. It contains an excess of acid. On evaporation it yields a kind of jelly, which when dry separates into gritty particles like sand. It is soluble in 96 parts of hot water. In the fire it readily melts into a white mass. If the heat be continued the acid separates, and there remains a transparent glass, which is soluble in water, and forms a *liquor silicum* †.

11. Fluat of iron. It is incrySTALLIZABLE; but when evaporated leaves a hard mass.

12. Fluat of zinc. It resembles that of iron.

13. Fluat of manganese. It may be formed by pouring fluat of ammonia into a solution of oxide of zinc in any of the three mineral acids. It crystallizes.

14. Fluat of cobalt. A yellow gelatinous mass.

15. Fluat of nickel. It affords green crystals.

16. Fluat of lead. A sweet tasted powder.

17. Fluat of tin. A nauseous tasted jelly.

18. Fluat of copper. Blue crystals; some of them oblong, others cubic.

19. Fluat of arsenic. Small crystals.

20. Fluat of mercury. A powder. Before the blow-pipe it melts into a yellow glass, most of which evaporates by a continued heat ‡.

SECT. X: Of Carbonats.

THE compounds into which the carbonic acid enters are called *carbonats*. They were first analysed by Dr Black.

1. Carbonat of potafs. This salt is formed by saturating potafs with carbonic acid, which is best done by exposing a solution of potafs for a considerable time to carbonic acid gas.

It crystallizes, according to Bergman, in quadrangular prisms; the apexes of which are composed of two inverted triangles, converging like the roof of a house ||. According to Pelletier they are tetrahedral rhomboidal prisms, with dihedral summits. The complete crystal has eight faces, two hexagons, two rectangles, and four rhombs ¶.

764
 Magnesia,

* Bergman,
 ii. 384.
 765
 Alumina,
 766
 Silica,

† Scheele,
 Crell's Jour-
 nal, i. 207.
 Eng. Transl.
 767

Metall-
 ing fluat of ammonia into a solution of oxide of zinc in fluats.

‡ Scheele on
 Fluor.

768
 Carbonat
 of potafs.

|| Bergman

* Ann. de
 Chim. xv.
 It 29.

Carbonats. It has an alkaline, but not a caustic taste. It is soluble at the common temperature in about four times its weight in water*. Boiling water dissolves $\frac{2}{3}$ ths of its weight †. Alcohol, even when hot, does not dissolve above $\frac{1}{1200}$ parts of it.

According to Bergman, it is composed of 48 parts of potash, 20 of acid, and 32 of water. According to Pelletier, of 43 parts of acid, 40 of potash, and 17 of water. Bergman under-rated the quantity of acid from not observing that the salt loses part of its acid when heated. Even solution in hot water produces a separation of some acid ‡.

It is not altered by exposure to the air.

Heat deprives it of its water and part of its acid, but does not decompose it completely. The following salts decompose it by compound affinity :

Sulphat of lime,	Nitrat of barytes,
———— barytes,	———— foda,
———— foda,	———— ammonia,
———— ammonia,	———— magnesia,
———— magnesia,	———— alumina,
———— alumina,	Acetite of barytes,
Muriat of barytes,	———— lime,
———— lime,	———— ammonia,
———— ammonia,	———— magnesia,
———— magnesia,	———— alumina,
———— alumina,	Oxy-muriat of mercury,
———— foda §,	Phosphat of lime .
Nitrat of lime,	

When potash is saturated with carbonic acid it always lets fall a quantity of silica. Mr Pelletier has proposed this saturation as the best method of purifying potash from that earth.

2. Carbonat of foda. This salt may be formed in the same manner with carbonat of potash.

Its crystals are five-sided prisms, with one of the angles frequently truncated, surmounted by dihedral pyramids with rhomboidal faces.

Its taste is precisely the same with that of carbonat of potash.

It is soluble in double its weight of cold water.

It is composed, according to Bergman, of 16 parts of acid, 20 of alkali, and 64 of water.

It effloresces when exposed to the air. Heat is incapable of decomposing it completely ¶.

The following salts decompose it by compound affinity :

Sulphat of ammonia,	Acetite of barytes,
———— barytes,	———— ammonia,
———— lime,	———— lime,
———— magnesia †,	———— magnesia,
———— alumina,	———— alumina,
Muriat of barytes,	Nitrat of ammonia,
———— ammonia,	———— magnesia,
———— lime,	———— alumina,
———— magnesia,	———— lead*,
———— alumina,	Phosphat of lime ‡.

3. Carbonat of ammonia. This salt forms octahedral crystals, having for the most part their two opposite apexes truncated †.

Its taste and smell, though much weaker, are the same with those of pure ammonia. Like all the alkaline carbonats it converts vegetable blues to green, precisely as pure alkalies do.

It is soluble in rather less than twice its weight of

cold water. Hot water dissolves its own weight of it. **Carbonats.**

According to Bergman it is composed of 43 parts of alkali, 45 of acid, and 12 of water.

When exposed to the air it becomes somewhat moist.

The smallest heat is sufficient to evaporate it.

The following salts decompose it by compound affinity :

Sulphat of alumina,	Acetite of barytes,
Nitrat of lime,	———— lime,
Muriat of lime,	———— magnesia,
———— magnesia,	———— alumina.
———— alumina,	

4. Carbonat of barytes. This salt has been found native. ⁷⁷¹ Carbonat of barytes,

Its crystals have been observed to assume four different forms; double six-sided and double four-sided pyramids, six-sided columns terminated by a pyramid with the same number of faces, and small radiated crystals $\frac{1}{2}$ an inch in length, and very thin, appearing to be hexagonal prisms, rounded towards the point.

Cold water dissolves $\frac{1}{1100}$ part, and boiling water $\frac{1}{100}$ part of this salt. Water saturated with carbonic acid dissolves $\frac{1}{3100}$ part*.

According to Dr Withering, who first discovered it native, it is composed of 80 parts of barytes and 20 of acid. Bergman informs us, that artificial carbonat is composed of 7 parts of acid, 28 of water, and 65 of earth †. ^{Ann. de Chim. iv. 64.}

It is not altered by exposure to the air.

It is decomposed by the application of a very violent heat ‡.

By compound affinity it is decomposed by the following salts :

Sulphat of foda,	Nitrat of alumina,
———— lime,	Muriat of lime,
———— ammonia,	———— ammonia,
———— magnesia,	———— magnesia,
———— alumina,	———— alumina,
Nitrat of foda,	Acetite of lime,
———— lime,	———— magnesia,
———— ammonia,	———— alumina.
———— magnesia,	

5. Carbonat of lime. This substance, under the names of marble, chalk, lime-stone, &c. exists in great abundance in nature, variously mixed with other bodies. ⁷⁷² Carbonat of lime.

When pure, it is of a white colour, and has very little taste.

It is insoluble in pure water; but water saturated with carbonic acid dissolves $\frac{1}{1300}$ part of it; from this solution it gradually precipitates as the acid leaves it in the form of small rhomboidal crystals §.

It is composed, according to Bergman, of 34 parts of acid, 11 of water, and 55 of lime. ^{§ Bergman, i. 21.}

It suffers little or no alteration by being exposed to the air.

When exposed to heat, it first loses its water, and afterwards its acid separates as the heat is increased: But to separate the acid completely, a very strong heat is required.

The following salts decompose it by compound affinity :

Sulphat of alumina,
———— copper.

6. Carbonat of strontites. This salt, which was first examined by Dr Hope, is insipid, and soluble in 1536 of strontites, ⁷⁷³ Carbonat of strontites,

Carbonats. parts of boiling water. It is composed of 30,2 parts of acid, 69,8 of frontites. A violent heat decomposes it *.
 * Hope, 774
 Transf. Edin. iv. 5.
 Carbonat of magnesia. It dissolves in water saturated with carbonic acid; and forms by evaporation crystals, which are transparent hexagonal prisms, terminated by a hexagonal plane; these are partly in groups and partly solitary: their length is about six lines, their breadth two †. They were discovered by Mr Butini of Geneva.

Water at the temperature of 50 dissolves $\frac{1}{8}$ part of its weight of this salt †. When in the state of powder, and of course deprived of its water of crystallization, it is much more insoluble; and what is very remarkable, it is more soluble in cold than in hot water, impregnated with carbonic acid §.

It is composed, according to Fourcroy, of 50 parts of acid, 25 of magnesia, and 25 of water.
 When exposed to the air, it effloresces, and falls into powder ||.

When heated, it decrepitates, falls into powder, and is decomposed ¶.
 The following salts decompose it by compound affinity:

- Sulphat of lime,
- ammonia,
- alumina,
- Nitrat of lime,
- Muriat of lime,
- Acetite of lime.

775
 Carbonat of alumina. 8. Carbonat of alumina. Carbonic acid is capable of dissolving alumina; for if alum be decomposed by an alkaline carbonat, some alumina remains dissolved in the liquor, and may be precipitated by a heat sufficient to drive off the carbonic acid *. It cannot be doubted, then, that there may be produced a carbonat of alumina; but the salt has never been examined with accuracy.

* Bergman, i. 21.
 776
 Metallic carbonats. 9. Carbonat of iron. Water saturated with carbonic acid dissolves $\frac{1}{10}$ part of its weight of iron, which gradually precipitates by exposure to the air †. Rust of iron is a kind of carbonat, at least it always contains carbonic acid.

10. Carbonat of zinc. Zinc is copiously dissolved by water saturated with carbonic acid †. As the metallic oxides, when saturated with carbonic acid, do not differ materially in their appearance from pure oxides, we shall not attempt to describe any of the metallic carbonats. We shall, however, present our readers with the following Table, exhibiting a view of the weight which metallic oxides gain by being saturated with this acid.

100 parts of	Precipitated by	
	By Bergman. Carb. of Soda. Weight.	By Wenzel. Carb. of Potash. Weight.
Oxide of zinc, - - -	100,930	100,774
iron, - - -	100,250	100,863
manganese, - - -	100,800	
cobalt, - - -	100,600	
nickel, - - -	100,350	
lead, - - -	100,320	100,304
tin, - - -	100,310	100,345
copper, - - -	100,940	100,884
bismuth, - - -	100,300	100,224
antimony, - - -	100,400	100,395
mercury, - - -	100,100	100,062
silver, - - -	100,290	100,288
gold, - - -	100,060	100,326

Quantity of loss by driving off the gas by solution according to Wenzel:

Metal	Loss
Zinc, - - -	0,137
Iron, - - -	0,009
Cobalt, - - -	0,352
Lead, - - -	0,157
Tin, - - -	0,000
Copper, - - -	0,174
Bismuth, - - -	0,056
Antimony, - - -	0,000
Mercury, - - -	0,038
Silver, - - -	0,158
Gold, - - -	0,144

These determinations differ too widely from each other to be exact. It is obvious that part of the weight must be owing to adhering water, and very probably triple salts are formed, which must render the determination still more erroneous.

SECT. XI. Of Acetites.

The compounds which the acetous acid forms are called acetites.

1. Acetite of potash. Pliny is supposed, but probably without any reason, to have been acquainted with this salt, because he recommends a mixture of vinegar and vine ashes as a cure for a particular species of tumor *. It was first clearly described by Raymond Lully. * Plinii, l. It has received a great number of names; as, for instance, *arcantum tartari, secret foliated earth of tartar, essential salt of wine, regenerated tartar, diuretic salt, digestive salt of Sylvius.*

Its crystals are very white, and assume the form of thin plates.

It has a sharp warm taste.

It is soluble in about ten times its weight of water at the temperature of 60° †. It is soluble also in alcohol. † Bergman, v. 78.

According to Wenzel, 240 parts of acetous acid require for saturation 241 $\frac{1}{2}$ ths of potash. And from the experiments of Dr Higgins, it appears that acetite of potash is composed of 61,5 parts of alkali and 38,5 of acetous acid and water ‡.

When exposed to the air it is very deliquescent. When heated, it melts as readily as wax; and if a very strong heat be applied, the acid is decomposed.

The following salts decompose it by compound affinity:

- Sulphat of soda,
- lime,
- ammonia,
- magnesia,
- alumina,
- Nitrat of soda,
- lime,
- Nitrat of ammonia,
- magnesia,
- alumina,
- bismuth,
- mercury,
- Muriat of ammonia,
- alumina.

2. Acetite of soda. This salt was first described by Mr Baron.

Its crystals are striated prisms, not unlike those of sulphat of soda.

It has a sharp taste, approaching to bitter.

It is soluble in 2,86 parts of water at the temperature of 60° §.

According to Wenzel, 440 parts of acetous acid require for saturation 157 $\frac{1}{2}$ ths of soda.

It is not affected by exposure to the air.
 When heated, it first loses its water of crystallization;

Acetites. in a strong heat it melts; and in a still stronger, its acid is destroyed. This salt can only be obtained in crystals when there is an excess of alkali in the solution.

The following salts decompose it by compound affinity :

Sulphat of ammonia,	Nitrat of alumina,
———— alumina,	Muriat of lime,
Nitrat of ammonia,	———— ammonia,
———— magnesia,	———— magnesia.

779 **Acetite of ammonia.** 3. Acetite of ammonia. This salt was formerly called *Spirit of Mindererus*.

It is too volatile to be easily crystallized : It may, however, by gentle evaporation, be made to deposit needle-shaped crystals. Mr de Laffone crystallized it by sublimation *. When the sublimation is slow, it forms long, slender, flattened crystals, terminating in sharp points, of a pearl white colour, and about an inch and eight-tenths in length †.

It impresses the tongue at first with a sense of coldness, and then of sweetness, which is followed by a taste resembling that of a mixture of sugar and nitre, in which the sweet does not predominate over the mawkish taste of the nitre ‡.

According to Wenzel, 240 parts of acetous acid saturate 244 of ammonia.

It is very deliquescent. It melts at 170°, and sublimes at about 250° §.

When a watery solution of this salt is distilled, there comes over first a quantity of ammonia, next a quantity of acetous acid, and at last of the neutral salt itself. No such decomposition takes place when the crystals are distilled by a moderate heat ||.

The following salts decompose acetite of ammonia by compound affinity :

Sulphat of alumina,	Carbonat of soda,
Carbonat of potash,	Nitrat of silver ¶.

¶ **Ibid.** p. 193. 780 **Acetite of barytes.** 4. Acetite of barytes. This salt was first formed by Mr Morveau.

It is not easily crystallized. Morveau procured it in long prisms in groups.

It has a pleasant, somewhat acid taste, and always contains an excess of acid.

It is soluble in water, and does not deliquesce when exposed to the air *.

The following salts decompose it by compound affinity :

Sulphat of potash,	Nitrat of alumina,
———— soda,	Muriat of potash,
———— lime,	———— soda,
———— ammonia,	———— lime,
———— magnesia,	———— ammonia,
———— alumina,	———— magnesia,
Nitrat of potash,	———— alumina,
———— soda,	Carbonat of potash,
———— lime,	———— soda,
———— ammonia,	———— ammonia.
———— magnesia,	

781 **Acetite of lime.** 5. Acetite of lime. This salt was first described accurately by Crollius. The ancients, however, used a mixture of lime and vinegar in surgery †.

It crystallizes in fine needles, of a glossy appearance like fatin.

Its taste is bitter and sour, because it has an excess of acid.

It is soluble in water.

According to Wenzel, 240 parts of acetous acid require for saturation 125 of lime : according to Maret, 100 parts of acetite of lime contain 50 of lime *. From the experiments of Dr Higgins, it follows, that acetite of lime is composed of 35,7 parts of lime and 64,3 of acetous acid and water †.

It is not altered by exposure to the air ; at least Morveau kept some of it for a whole year merely covered with paper, and even quite uncovered for a month, without its undergoing any alteration ‡.

Heat decomposes it, and at the same time partly decomposes its acid.

The following salts decompose it by compound affinity :

Sulphat of soda,	Muriat of alumina,
———— ammonia,	Carbonat of barytes,
———— magnesia,	———— potash,
———— alumina,	———— soda,
Nitrat of ammonia,	———— ammonia,
———— magnesia,	———— magnesia,
———— alumina,	———— alumina.

Muriat of ammonia, 782 **Acetite of strontites.** This salt was first formed by Dr Hope. It forms small crystals, which are not affected by exposure to the atmosphere. 49 parts of it are soluble in 120 parts of boiling water : It seems to be nearly as soluble in cold water. It renders vegetable colours green §.

7. Acetite of magnesia. This salt was first mentioned by Mr Wenzel.

It is not crystallizable ; but forms by evaporation a viscid mass ||.

It has a sweetish taste ; leaving, however, a sense of bitterness ¶.

It is very soluble both in water and alcohol *.

According to Wenzel, 240 parts of acetous acid require for saturation 123½ths of magnesia.

When exposed to the air, it deliquesces. Heat decomposes it.

The following salts decompose it by compound affinity :

Sulphat of ammonia,	Carbonat of barytes,
———— alumina,	———— potash,
Nitrat of ammonia,	———— soda,
———— alumina,	———— ammonia,
Muriat of ammonia,	———— alumina.
———— alumina,	

8. Acetite of alumina. This salt can only be formed by digesting acetous acid on alumina recently precipitated. 784 **Acetite of alumina.**

By evaporation needle-shaped crystals are obtained, which are very deliquescent. According to Wenzel, 240 parts of acetous acid require 20½ths of alumina for saturation.

This salt is decomposed by compound affinity by the following salts :

Nitrat of ammonia,	Carbonat of potash,
Muriat of ammonia,	———— soda,
Carbonat of barytes,	———— ammonia.

9. Acetite of jargonina. This salt may be formed by pouring acetous acid on newly precipitated jargonina. 785 **Acetite of jargonina.**

It has an astringent taste. It does not crystallize ; but when evaporated to dryness, it forms a powder, which does not attract moisture from the air as acetite of alumina does †.

It is very soluble in water and in alcohol. 786 **Acetite of alumina.**

* *Fncyc. Method. Chim.* i. 9.
† *On Acetous Acid*, p. 47.
‡ *Ibid.* *Encyc. Method.*
§ *Dr Hope, Transf. Edin.* iv. 14.
|| *Bergman, ii.* 388.
¶ *Morveau, ibid.*
* *Bergman, ii.* 388.

* *Mem. Par. i.* 775.
† *Higgins on Acetous Acid*, p. 188.
‡ *Higgins, ibid.* p. 192.
§ *Ibid.*

¶ *Ibid.* p. 193.
780 *Acetite of barytes.*

* *Morveau, Encyc. Method. Chim.* i. 8.
781 *Acetite of lime.*

† *Plinii, l. xxvi.* c. 24.
† *Kl. protb, Journ. de Phys.* xxvi. hol. 188.

Acetites. hol. It is not so easily decomposed by heat as nitrat of jargonia, probably because it does not adhere to water *.

* *Vauquelin, Ann. de Chim. xxii. 206.*
786
Acetite of iron.

10. Acetite of iron.—This salt was mentioned by Schröder and Juncker. It is composed of acetous acid and brown oxide of iron.

Its solution forms by gentle evaporation small oblong crystals; but the greatest part of the salt assumes the form of a gelatinous mass †.

† *Wenzel.*
It has a sweetish styptic taste.
According to Wenzel, 240 parts of acetous acid require for saturation 186½ of iron.

Heat decomposes this salt; and it seems also to be gradually decomposed by exposure to the air.

787
Acetite of zinc.

11. Acetite of zinc.—This salt was first mentioned by Glauber.

Its crystals are rhomboidal, and sometimes hexagonal plates, of a white colour, and the appearance of talk.

It is soluble in water. According to Wenzel, 240 parts of acetous acid require for saturation 195½ths of zinc.

It is not altered by exposure to the air. Heat decomposes it. When thrown upon burning coals, it explodes with a blue flame.

12. Acetite of manganese.—This salt is not crystallizable; and when evaporated to dryness, it deliquesces. Is it not an acetat ?

788
Acetite of cobalt.

13. Acetite of cobalt.—This salt is deliquescent. Its solution is of a fine red colour while cold; but becomes blue by being heated, and it recovers its former colour on cooling. According to Wenzel, 240 parts of acetous acid require for saturation 241½ths of cobalt.

789
Acetite of nickel.

14. Acetite of nickel.—This salt forms rhomboidal cubes of a green colour †: They are not deliquescent: Their taste is sweet §.

† *Bergman.*
‡ *Monnet.*
§ *Monnet.*
790
Acetite of lead.

15. Acetite of lead.—This salt is mentioned by Isaac Hollandus and Raymond Lully. It is composed of acetous acid and white oxide of lead.

It was formerly called *sugar of lead, sugar of Saturn, salt of Saturn, vinegar of Saturn, extract of Saturn, &c.*

Its crystals are flat parallelepipeds, terminated by two inclined planes approaching each other.

It has a sweet and somewhat astringent taste.
It is not very soluble in water; but acetous acid dissolves it abundantly.

According to Wenzel, 240 parts of acetous acid require for saturation 503 of lead.

When exposed to the air it becomes yellow, but undergoes no other alteration.

Heat decomposes it by destroying the acid. When distilled, the residuum takes fire spontaneously on exposure to the air. Paper dipped into acetite of lead forms excellent matches, which are not subject to go out, and which burn very slowly.

The following salts decompose it by compound affinity:

Muriat of ammonia, Phosphat of ammonia,
Sulphat of copper, Oxalat of potash ||,
Phosphat of soda, Malat of potash ¶.

791
Acetite of tin.

16. Acetite of tin.—This salt was first described by Lemery.

¶ *Scheele*
¶ *Id.*
* *Morveau.*
Its crystals are prismatic needles in groups*. According to Wenzel, 240 parts of acetous acid require for saturation 3¼ of tin.

17. Acetite of copper.—This salt was known to the ancients, and various ways of preparing it are described by Pliny*. It was formerly known by the names of *crystals of Venus and verdigrise.*

Acetite of copper. * *Lib. xxxiv. c. 11.*
It is of a deep green colour. Its crystals are rhomboids.

It has a disagreeable coppery taste.

It is soluble in water and in alcohol.

According to Wenzel, 240 parts of acetous acid require 16¼th of copper for saturation.

It effloresces when exposed to the air. Heat decomposes it. It is used in painting.

793
Acetite of bismuth.

18. Acetite of bismuth.—This salt seems to have been first mentioned by Geoffroi. He called it *sugar of bismuth.*

It is most easily procured by mixing together the solutions of nitrat of bismuth and acetite of potash. It forms brilliant, talky, silvery crystals.

It has a sweetish taste. According to Wenzel, 240 parts of acetous acid require for saturation 15½ths of bismuth.

It does not deliquesce when exposed to the air. Heat decomposes it.

794
Acetite of antimony.

19. Acetite of antimony.—It yields with difficulty small crystals †. According to Wenzel, 240 parts of acetous acid require for saturation 1¼d of antimony.

795
Acetite of arsenic.

20. Acetite of arsenic.—This salt forms small crystals in grains, hardly soluble in water ‡.

† *Bergman.*
‡ *Bergman.*
796
Acetite of mercury.

21. Acetite of mercury.—This salt is mentioned by Schröder.

Its crystals are small thin plates.

It has a disagreeable taste, and excites coughing.

It is hardly soluble in water. According to Wenzel, 240 parts of acetous acid require for saturation 240½ths of mercury.

When exposed to the air it becomes black, owing to the reduction of the oxide of mercury. Heat decomposes it.

797
Acetite of silver.

22. Acetite of silver.—This salt was perhaps first described by Margraf.

It is best formed by dropping acetite of soda or potash into a saturated solution of nitrat of silver §.

§ *Maret.*
ibid.
It forms small oblong crystals, easily dissolved in water †. It has a sharp taste.

† *Margraf.*
According to Wenzel, 240 parts of acetous acid require for saturation 101½ths of silver.

Heat decomposes it. It is decomposed by muriat of magnesia ¶.

¶ *Bergman.*
798
Acetite of gold.

23. Acetite of gold.—This salt is mentioned by Schröder and Juncker.

799
Acetite of uranium.

24. Acetite of uranium.—This salt was first formed by Klaproth.

Its crystals are regular four-sided slender prisms, terminated at both ends by regular quadrilateral pyramids; they are transparent, and of a beautiful topaz yellow colour.

Heat decomposes them: and what is singular, if they be heated gradually red hot, the oxide which remains retains nearly the form of the crystals*.

* *Klaproth on Uranium.*
500
Acetats.
The compounds into which the acetic acid enters are called *acetats*. They are so imperfectly known at present, that we shall not attempt a description of them.

SECT. XII. Of Oxalats.

THE compounds of which oxalic acid forms a part

Oxalats. are known by the name of *oxalats*. They were first described by Bergman.

801 Oxalat of potafs. 1. Oxalat of potafs.—This falt cryftallizes with difficulty. It is very foluble in water. When heated it falls to powder *.

* Bergman, i. 262. 802 Acidulous oxalat of potafs. 2. Acidulous oxalat of potafs.—The oxalic acid is alfo capable of combining with potafs in excefs, and forming another falt, called *acidulous oxalat* from its acid tafte; or, to fpeak more accurately, this falt is formed by the combination of oxalat of potafs with oxalic acid. This falt exifts ready formed in *oxalis acetofella* or wood-forrel; from which it is extracted in fome parts of Europe in great quantities. Hence it was formerly called falt of wood forrel. It is mentioned by Duclos in the Memoirs of the French Academy for 1668. Margraf firft proved that it contained potafs; and Scheele difcovered that its acid is the oxalic. A great many interefting experiments had been previously made on it by Wenzel and Wiegleb.

It may be formed, as Scheele has fown, by dropping potafs very gradually into a faturated folution of oxalic acid and water: as foon as the proper quantity of alkali is added, acidulous oxalat is precipitated. But care muft be taken not to add too much alkali, otherwife no precipitation will take place at all.

† De Lifle. Its cryftals are fmall opaque parallelopeds †.

It has an acid, poignant, bitterifh tafte.

It is foluble in about ten times its weight of boiling water, but much lefs foluble in cold water.

It is not altered by expofure to the air. Heat decomposes it.

This falt is fold in this country under the name of *effential falt of lemons*.

803 Oxalat of foda. 3. Oxalat of foda.—This falt agrees very much with oxalat of potafs. Its cryftals are fmall, and foluble in water.

From Bergman's defcription, oxalic acid appears alfo capable of combining in excefs with foda, and forming an acidulous oxalat.

804 Oxalat of ammonia. 4. Oxalat of ammonia.—Its cryftals are four-fided prifms, generally diverging from various points. They redder the infufion of turnfole.

† Bergman. They are eafily foluble in water, but not in alcohol †.

§ Bergman, *ibid.* It is decomposed by nitrat of barytes §.

805 Earthy oxalats. 5. Oxalat of barytes.—This falt does not cryftallize except with excefs of acid. The addition of potafs, or even of water, deprives it of this excefs, and then it crumbles into powder. It is infoluble in water †.

¶ Bergman, *ibid.* 6. Oxalat of lime.—This falt does not cryftallize. It is infoluble in water, but fomewhat foluble in acids. It is compofed of 48 parts of acid, 46 of lime, and 6 of water. Heat decomposes it ¶.

¶ Bergman, *ibid.* 7. Oxalat of ftrontites.—This falt was firft formed by Dr Hope. It is a white infipid powder; foluble in 1920 parts of boiling water. Heat decomposes it by deftroying the acid *.

* Hope, *Transf. Edin.* iv. 14. 8. Oxalat of magnesia.—This falt is in the form of a white powder. It is fcarcely foluble either in water or alcohol. It is compofed of 35 parts of magnesia and 65 of acid and water. Heat decomposes it †.

† Bergman, *ibid.* and ii. 327. 9. Oxalat of alumina.—It is uncrystallizable; but furnifhes on evaporation a yellowifh pellucid mafs. It is fparingly foluble in alcohol. It has a fweet astringent tafte. It is compofed of 44 parts of alumina and 56 of acid and water.

When expofed to the air it deliquesces; and if it has been previously well dried, its weight is increased by $\frac{3}{7}$. It reddens turnfole *.

10. Oxalat of iron.—This falt forms prifmatic cryftals of a yellowifh green colour.

It has an astringent and fweet tafte. It is very foluble in water.

It is compofed of 45 parts of green oxide, and 55 of acid and water. When expofed to heat it falls to powder †.

From Bergman's defcription, the brown oxide of iron appears alfo capable of combining with oxalic acid. The compound does not cryftallize, and is nearly infoluble in water †.

† *Ibid.* 11. Oxalat of zinc.—It is hardly foluble in water.

It is compofed of 75 parts of oxide and 25 of acid.

12. Oxalat of manganese.—It is compofed of oxalic acid and white oxide of manganese. It appears capable of cryftallizing §.

§ *Ibid.* 13. Oxalat of cobalt.—This is a rofe-coloured powder, infoluble in water, but foluble in oxalic acid; and capable, by that means, of cryftallizing †.

¶ *Ibid.* 14. Oxalat of nickel.—This is a green-coloured powder, hardly foluble in water. It is compofed of two parts of acid and one of oxide ¶.

¶ *Ibid.* 15. Oxalat of lead.—It forms fmall cryftalline grains. They are infoluble in alcohol, and nearly infoluble in water. They contain 55 parts of oxide and 45 of acid *.

* *Ibid.* 16. Oxalat of tin.—This falt forms prifmatic cryftals. It has an auftere tafte. If the folution of this falt be quickly evaporated, it affords a mafs refembling horn, and foluble in water †.

† *Ibid.* 17. Oxalat of copper.—This falt is uncrystallizable. It is a bluish powder, infoluble in water, except with excefs of acid. It is compofed of 21 parts of copper and 29 of acid †.

† *Ibid.* 18. Oxalat of bismuth.—This falt may be formed by dropping oxalic acid into a folution of nitrat of bismuth. It forms pellucid polygonous cryftals. When oxide of bismuth is difsolved by oxalic acid, the refult is a white powder, fcarcely foluble in water §.

§ *Ibid.* 19. Oxalat of antimony.—This falt forms cryftalline grains, with difficulty foluble in water †.

† *Ibid.* 20. Oxalat of arsenic.—This falt is compofed of oxalic acid and white oxide of arsenic. Its cryftals are prifms very foluble in water and alcohol. It reddens turnfole.

Heat fublimes it; and by a ftrong heat it may be decomposed ¶.

¶ *Ibid.* 21. Oxalat of mercury.—A white powder, hardly foluble in water, except with excefs of acid *.

* *Ibid.* 22. Oxalat of filver.—This falt may be formed by pouring oxalic acid into a folution of nitrat of filver. It is a white powder, fcarcely foluble in water, and not at all in alcohol; but foluble in nitric acid. It becomes black by being expofed to the air, owing to the reduction of the oxide †.

† *Ibid.* 23. Oxalat of platinum.—This falt affords yellow cryftals.

SECT. XIII. Of Tartrites.

THE falts into which tartarous acid enters as an ingredient are known by the name of *tartrites*.

807 1. Acidulous oxalat of potafs or tartar.—This falt, Tartar, which is compofed of potafs and an excefs of tartarous acid, or rather of tartrite of potafs and tartarous acid, has

Tartrites. has been long known. It is obtained in a state of impurity at the bottom, and adhering to the sides of casks in which wine has fermented. It is called *tartar*, says Paracelsus, because it produces the oil, water, limestone, and salt, which burn the patient as *Hell* does. According to him, it was the principle of every disease and every remedy, and all things contain the germ of it.

Margraf and Rouelle first demonstrated that it contained potash ready formed; and Scheele first obtained tartarous acid from it in a state of purity.

Its crystals are very small and irregular. According to Montet, they are prisms, somewhat flat, and mostly with six sides. It has a strong acid taste. It is soluble in about 30 times its weight of boiling water*. According to Bergman, it contains 23 parts of alkali and 77 of acid.

It is not altered by exposure to the air. Heat decomposes it, and at the same time destroys the acid. It is capable of forming a great many compounds.

808
Tartrite of potash. 2. Tartrite of potash. This salt may be formed by saturating the last described salt with potash. It was formerly called *soluble tartar*, because it is much more soluble in water than the acidulous tartrite of potash. It crystallizes most readily when there is a small excess of alkali in the solution. Its crystals are small oblongs.

It has an unpleasant bitter taste. It is soluble in 4 parts of water at the temperature of 40°.

3. Tartrite of soda. This salt has never been accurately examined.

809
Tartrite of potash and soda. 4. Tartrite of potash and soda. This triple salt, formerly known by the name of *salt of Seignette*, because first formed by Mr Seignette apothecary at Rochelle, is made by saturating tartar with soda.

Its crystals are prisms of eight or ten unequal sides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes, and the base on which they stand is marked with two diagonal lines, so as to divide it into four triangles.

It has a bitter taste. It is almost as soluble as tartrite of potash.

It effloresces when exposed to the air. Heat decomposes it.

810
Tartrite of ammonia. 4. Tartrite of ammonia. The crystals of this salt are polygonous prisms, not unlike those of the last described salt.

It has a cooling bitter taste like that of nitre. It is easily soluble in water. Heat decomposes it.

5. Acidulous tartrite of ammonia. This salt may be formed by pouring tartarous acid into a solution of tartrite of ammonia. Like acidulous tartrite of potash it is very insoluble in water.

6. Tartrite of potash and ammonia. This triple salt may be formed by pouring ammonia into acidulous tartrite of potash.

Its crystals, according to Macquer, are prisms with four, five, or six sides: according to the Dijon academicians, parallelepipeds, with two alternate sloping sides.

It has a cooling taste. It is soluble enough in water. It effloresces in the air. Heat decomposes it.

7. Tartrite of barytes. Unknown.

811
Earthy tartrites. 8. Tartrite of lime. This salt, first formed by Scheele, is a tasteless and almost insoluble powder. By heat the acid is decomposed, and the pure lime remains behind.

9. Tartrite of stontites. This salt was first formed

by Dr Hope. Its crystals are small regular triangular tables, having the edges and angles sharp and well defined. It is insipid. It dissolves in 320 parts of boiling water.

It is not altered by exposure to the air. Heat decomposes it by destroying the acid*.

10. Tartrite of magnesia. This salt is insoluble in water except there be an excess of acid present. It then affords by evaporation small crystals in the form of hexangular truncated prisms †.

It has a more saline taste, and is more fusible, than tartrite of lime ‡.

Heat first melts and afterwards decomposes it.

11. Tartrite of alumina. This salt does not crystallize, but forms by evaporation a clear transparent gummy mass. Its taste is astringent. It is soluble in water. It does not deliquesce in the air §.

12. Tartrite of potash and alumina. This triple salt is formed by saturating tartar with alumina. It bears a very striking resemblance to the last described salt.

812
Metallic tartrites. 13. Tartrite of iron. This is a grey powder. When tartarous acid is poured into a solution of sulphat of iron, scaly crystals are formed by evaporation. These crystals are doubtless composed of tartarous acid combined with sulphat of iron. This triple salt might be called *tarthro-sulphat of iron*.

14. Tartrite of potash and iron. This triple salt was formerly called *tartarised tincture of Mars*, *chalybeated tartar*, and *tartarised iron*. It may be formed by boiling two parts of tartar and one of iron filings, previously made up into a paste, in a proper quantity of water. The liquor by evaporation deposits crystals, which form the salt wanted.

15. Tartrite of zinc. This salt is not easily soluble in water.

16. Tartrite of potash and zinc. This triple salt, formed by combining tartar and oxide of zinc, is very soluble in water ||.

17. Tartrite of lead. This salt, which is composed of tartarous acid and white oxide of lead, is almost insoluble in water. Nitric acid dissolves it.

18. Tartrite of potash and lead. This salt, formed by combining white oxide of lead with tartar, is very soluble in water ¶.

19. Tartrite of tin. Unknown. The tartrite of potash and tin, composed of tartar and oxide of tin, is capable of crystallizing.

20. Tartrite of copper. This salt is best formed by pouring tartarous acid into the solutions of muriat or sulphat of copper; it precipitates in the form of blue crystals*.

This salt forms the best kind of the pigment called *Brunswick green* †.

21. Tartrite of potash and copper. This triple salt is also in the form of blue crystals.

22. Tartrite of bismuth. Small crystalline grains ‡. † Bergman.

23. Tartrite of antimony. This salt has never been examined with attention.

24. Tartrite of potash and antimony, or tartar emetic. To this salt, which is perhaps the most powerful emetic known, a great deal of attention has been paid, and a vast number of methods have been tried to prepare it. These methods have been already described in the Encyclopædia. It appears from the experiments of Mr

Bindheim,

Tartrites.

* Hope, Edin. Transf. iv. 15.

† Bergman, ii. 288.

‡ Von Packen de Sale essent. acid. Tartar.

§ Von Packen.

|| Metallic tartrites.

¶ Elemens. de Chim. Dijon.

¶ Wenzel.

* Bergman.

† Leonhardi.

‡ Bergman.

Citrats. Bindheim, that if this salt be carefully prepared, the difference that results from the use of different oxides is not so great as might have been expected *.

* Ann. de Chim. xiii. 218.

It was first made known by Adrian in 1631. It is a triple salt, composed of tartar and white oxide of antimony.

It is of a white colour and transparent. Its crystals are trihedral pyramids.

It dissolves in 60 parts of cold water, and in a smaller proportion of hot water. It is decomposed by lime and alkalies, iron, &c. Care ought therefore to be taken to use only distilled water when it is administered as a medicine.

25. Tartrate of arsenic. This salt forms prismatic crystals very like those of oxalat of arsenic †.

† Bergman, i. 295. 26. Tartrate of mercury. A yellow powder.

† Monnet. 27. Tartrate of potash and mercury. This triple salt crystallizes †.

SECT. XIV. Of Citrats.

THE compounds into which the citric acid enters have been denominated *citrats*.

These salts are at present very imperfectly known.

§ Journ. de Phys. 1794, Supplement. 813 Alkaline citrats. Mr Dizé has promised soon to supply this defect §.

1. Citrat of potash. This salt does not crystallize. It has a cooling saline taste, and deliquesces when exposed to the air.

2. Citrat of soda. This salt does not deliquesce. It has a mild, pleasant, cooling taste ||. According to Scheele, it does not crystallize.

3. Citrat of ammonia. This salt crystallizes in thin needles. It has a cooling and moderately saline taste ¶. The ammonia is separated by the application of heat *.

4. Citrat of barytes. This salt is scarcely soluble in water. It assumes the form of a white powder †. It is soluble in citric acid.

5. Citrat of lime. This is a white powder, scarcely soluble in water †.

6. Citrat of magnesia. Does not crystallize. It forms a gummy saline mass very soluble in water §.

7. Citrat of alumina. This salt is scarcely soluble in water.

8. Citrat of iron. A solution of a brown colour.

9. Citrat of copper. A green gummy mass.

10. Citrat of mercury. This salt may be formed by pouring citric acid into nitrat or acetite of mercury. It is a flaky salt, of a brick-dust colour, more or less red ||.

SECT. XV. Of Malats.

THE compounds into which the malic acid enters are called *malats*. This class of salts was first discovered by Scheele. They are no better known than the citrats.

816 Malats. 1. Malat of potash. } These salts are deliquescent ¶.

¶ Scheele. 2. Malat of soda. }

3. Malat of ammonia. }

4. Malat of lime. Small irregular crystals. They require a large quantity of boiling water for their solution. With excess of acid they are readily soluble in cold water †. They are insoluble in alcohol †.

5. Malat of barytes. The properties of this salt resemble pretty much those of malat of lime §.

6. Malat of magnesia. Deliquescent ||.

† Id. † Id. § Id. § Id.

7. Malat of iron. A brown solution, not crystallizable *.

8. Malat of zinc. This salt forms beautiful crystals †. † Id.

SECT. XVI. Of Lactats.

THE neutral salts formed by the combination of the lactic acid with various bases are called *lactats*. They were first discovered by Scheele. 817 Lactats.

1. Lactat of potash. A deliquescent salt, soluble in alcohol †. † Scheele on Milk.

2. Lactat of soda. This salt does not crystallize. It is soluble in alcohol §.

3. Lactat of ammonia. Crystals which deliquesce. Heat separates a great part of the ammonia before destroying the acid.

4. Lactat of barytes. } These salts deliquesce ||. The lactat of lime is soluble in alcohol ¶.

5. Lactat of lime. }

6. Lactat of alumina. } Small deliquescent crystals *.

7. Lactat of iron. A brown solution.

8. Lactat of zinc. Crystals †. † Id.

These salts have a very strong resemblance to malats.

The only difference which Scheele observed was, that the malat of lime was insoluble in alcohol, while alcohol dissolved lactat of lime.

SECT. XVII. Of Saccholats.

THE compounds into which the saccholactic acid enters are called *saccholats*. They also were first discovered by Scheele. 818 Saccholats.

1. Saccholot of potash. Small crystals, soluble in eight times their weight of boiling water †.

2. Saccholot of soda. The same; soluble in five times their weight of boiling water §.

3. Saccholot of ammonia. A salt which has a sourish taste. Heat separates the ammonia ¶.

4. Saccholot of barytes. }

5. Saccholot of lime. } These salts are insoluble in water *.

6. Saccholot of magnesia. }

7. Saccholot of alumina. }

SECT. XVIII. Of Gallats.

THE compounds into which the gallic acid enters are denominated *gallats*. They were first attended to by the Dijon academicians and by Scheele. 819 Gallats.

1. Gallat of potash. } We only know that these

2. Gallat of soda. } compositions are possible,

3. Gallat of ammonia. } and that their properties are different from those of all other salts.

4. Gallat of barytes. } These salts are soluble in water,

5. Gallat of lime. } especially when there is excess of acid.

6. Gallat of magnesia. This salt is a yellow powder, soluble in water and in alcohol *.

7. Gallat of alumina. This salt, according to Bartholdi, exists ready formed in nut galls. It is very soluble in water. * Bartholdi Ann. de Chim. xii. 305.

8. Gallat of iron. This salt, which Mr Proust has discovered to be formed of gallic acid and brown oxide of iron, is of a black colour, and does not seem capable of crystallizing. It is soluble in the three mineral acids, and by that means is deprived of its black colour. It is to this salt that ink partly owes its black colour. Gallat of iron is decomposed by alkalies.

We shall not attempt any farther account of this class of

Benzoats. of salts. Scarcely any addition has yet been made to the experiments of Scheele which have been given already in the article CHEMISTRY, *Encycl.*

SECT. XIX. *Of Benzoats.*

820
Alkaline
benzoats. THE compounds into which the benzoic acid enters have been called *benzoats*.

1. Benzoat of potash. This salt forms pointed feathery crystals. It has a saline sharp taste. It is very soluble in water. It deliquesces when exposed to the air*.

* *Keir's Dictionary.*
2. Benzoat of soda. The crystals of this salt are larger, but its taste is the same with that of benzoat of potash. It is also very soluble in water. It effloresces in the air †.

† *Ibid.*
3. Benzoat of ammonia. This salt crystallizes with difficulty. Its crystals are feather-shaped. It deliquesces ‡.

‡ *Ibid.*
821
Earthy
benzoats. 4. Benzoat of lime. This salt forms white, shining, pointed crystals, of a sweetish taste, and not easily soluble in water §.

§ *Ibid.*
5. Benzoat of magnesia. Feather-shaped crystals, of a sharp bitter taste, and easily soluble in water †.

† *Ibid.*
822
Metalline
benzoats. 6. Benzoat of alumina, an astringent salt.
7. Benzoat of iron. This salt forms yellow crystals. It has a sweet taste. It is soluble in water and alcohol.

¶ *Trommsdorff, Ann de Chim. xi. 314.*
It effloresces in the air. Heat disengages the acid ¶.
8. Benzoat of zinc. This salt forms arborescent crystals. It is soluble in water and alcohol. When exposed to the air it is dissipated. Heat decomposes it*.

* *Id. ibid.*
9. Benzoat of manganese. This salt, which is formed of benzoic acid and white oxide of manganese, crystallizes in small scales. It dissolves readily in water; with difficulty in alcohol. It is not altered by exposure to the air †.

† *Id. ibid.*
10. Benzoat of cobalt. Flat crystals ‡.

‡ *Id. ibid.*
11. Benzoat of lead. Very white crystals, soluble in water and alcohol. They are not altered by exposure to the air. Heat disengages the acid §.

§ *Id. ibid.*
12. Benzoat of tin. This salt may be formed by pouring benzoat of potash into a solution of tin in the nitro-muriatic acid. The benzoat of tin is precipitated. It is soluble in hot water, but insoluble in alcohol. Heat decomposes it ||.

|| *Id. ibid.*
13. Benzoat of copper. Small crystals of a deep green colour. They are with difficulty soluble in water, and not at all in alcohol ¶.

¶ *Id. ibid.*
14. Benzoat of bismuth. This salt forms white needle-shaped crystals. They are soluble in water, and in a very small proportion in alcohol. They are not altered by exposure to the air. Heat decomposes them*.

* *Id. ibid.*
15. Benzoat of antimony. Crystals which effloresce in the air, and are decomposed by heat †.

† *Id. ibid.*
16. Benzoat of arsenic. Small feather-shaped crystals. It is soluble in hot water, but crystallizes in the cooling. A moderate heat sublimes it; a strong heat decomposes it. Sulphur decomposes it. It is not decomposed by alkalies ‡.

‡ *Id. ibid.*
17. Benzoat of mercury. A white powder. It is insoluble in water, but dissolves in a small quantity in alcohol. It is not altered by exposure to the air. A small heat sublimes it; a greater decomposes it. It is decomposed by sulphur §.

§ *Id. ibid.*
18. Benzoat of silver. This salt is soluble in water,

and also in a very small proportion in alcohol. It is not altered by exposure to the air, but the rays of the sun render it brown. Heat disengages its acid*.

Camphorats.
* *Id. ibid.*

19. Benzoat of gold. Small irregular crystals, not easily soluble in water; insoluble in alcohol. It is not altered by exposure to the air. Heat decomposes it †.

† *Id. ibid.*

20. Benzoat of platinum. This salt forms small brownish crystals, with difficulty soluble in water; not soluble in alcohol. When exposed to heat, it is decomposed, and there remains behind a brown powder ‡.

‡ *Id. ibid.*

SECT. XX. *Of Succinats.*

THE neutral salts, formed by the combination of the succinic acid with various bases, have been called *succinats*.

We shall not describe these salts, as we could not add much to the account given in the Appendix to the article CHEMISTRY in the *Encycl.* That account was taken from Mr Kier's Chemical Dictionary, and that gentleman borrowed it from Leonhardi.

SECT. XXI. *Of Camphorats.*

THE neutral salts into the composition of which camphoric acid enters, have been denominated *camphorats*. The only chemist who has hitherto examined them is Bouillon la Grange: his experiments have been published in the 27th volume of the *Annales de Chimie*.

1. Camphorat of potash. To prepare this salt, carbonat of potash is to be dissolved in water, and the solution saturated with camphoric acid. When the effervescence is over, the liquor is to be evaporated by a gentle heat to the proper consistence, and crystals of camphorat of potash will be deposited when the liquor cools.

823
Camphorat
of potash.

Camphorat of potash is white and transparent; its crystals are regular hexagons. Its taste is bitterish and slightly aromatic.

Water at the temperature of 60° dissolves $\frac{1}{100}$ th part of its weight of this salt; boiling water dissolves $\frac{1}{3}$ th part of its weight.

It is soluble in alcohol, and the solution burns with a deep blue flame.

When exposed to moist air, it loses a little of its transparency, but in dry air it suffers no change.

When exposed to heat it melts, swells, and the acid is volatilized in a thick smoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potash remains behind in a state of purity.

By compound affinity this salt is decomposed by

Nitrat of barytes,
All the salts whose base is lime,
Nitrat of silver,
Sulphat of iron,
Muriat of tin,

————— lead §.

2. Camphorat of soda. This salt may be formed precisely in the same manner with the camphorat of potash.

§ *Bouillon La Grange, Ann. de Chim. xxvii.*

It is white and transparent; its taste is somewhat bitter; its crystals are irregular.

24.
824
Camphorat
of soda.

Water at the temperature of 60° dissolves less than $\frac{1}{100}$ th part of its weight of this salt; boiling water dissolves $\frac{1}{3}$ th of its weight.

It is also soluble in alcohol.

When exposed to the air it loses its transparency, and effloresces.

Camphorats. effloresces slightly, but is never completely reduced to powder.

Heat produces the same effect upon it as on camphorat of potass: the acid burns with a blue flame, which becomes reddish towards the end.

By compound affinity it is decomposed by

Nitrat of lime,	Muriat of lime,
———— silver,	———— iron,
Muriat of magnesia,	Sulphat of alumina,
———— barytes,	———— iron: and ma-
———— alumina,	ny other salts with me-

* *Bouillon* tallic bases *.

La Grange,
Ann. de
Chim. xxvii.
26.

3. Camphorat of ammonia. This salt may be prepared by dissolving carbonat of ammonia in hot water, and adding camphoric acid slowly till the alkali is saturated. It must then be evaporated with a very moderate heat, to prevent the disengaging of ammonia.

825
Camphorat
of ammo-
nia.

It is very difficult to obtain this salt in regular crystals. When evaporated to dryness, there is obtained a solid opaque mass of a sharp and bitterish taste.

Water at the temperature of about 60° dissolves nearly $\frac{1}{100}$ th part of its weight of this salt; boiling water dissolves $\frac{1}{3}$ d of its weight: But this and the two salts above described are a good deal more soluble when there is excess of base.

It is entirely soluble in alcohol.

When exposed to the air it attracts moisture, but not in sufficient quantity to enable it to assume a liquid form.

When exposed to heat it swells, melts, and is converted into vapour; before the blow-pipe it burns with a blue and red flame, and is entirely volatilized.

Most of the calcareous salts form triple salts with camphorat of ammonia.

It decomposes in part all the aluminous salts except the sulphat of alumina †.

† *Ibid.*
826

Camphorat
of barytes.

4. Camphorat of barytes. In order to prepare this salt, barytes is to be dissolved in water, and camphoric acid added to the solution; the mixture is then to be boiled, and afterwards filtered and evaporated to dryness.

Camphorat of barytes does not crystallize; when the evaporation is conducted slowly, the salt is deposited in thin plates one above another, which appear transparent while immersed in the liquor, but become opaque whenever they come into contact with the air.

It has very little taste, though it leaves at last upon the tongue a slight impression of acidity mixed with bitterness.

Water dissolves only a very small quantity of this salt, boiling water being capable of taking up only $\frac{1}{100}$ th part of it.

It is not altered by exposure to the air.

When exposed to heat it melts easily, and the acid is volatilized. When the heat is considerable, the acid burns with a lively blue flame, which becomes red and at last white.

It is decomposed by

Nitrat of potass,	soda,	lime,	ammonia,	and magnesia.
Muriat of lime,	potass,	alumina,	and magnesia.	
All the sulphats.				

Carbonat of potass and soda.

Phosphat of potass, soda, and ammonia *.

† *Bouillon*
La Grange,
ibid. p. 28.
827

5. Camphorat of lime. This salt may be prepared by dropping into lime-water crystallized camphoric acid.

The mixture is then to be made boiling hot, passed through a filter, and evaporated to about $\frac{1}{3}$ ths of its volume. On cooling, camphorat of lime is deposited.

Campho-
rats.

It has no regular shape; but if the evaporation has been properly conducted, it is in plates lying one above another. It is of a white colour, and has a taste slightly bitter.

Water at the temperature of 60° dissolves very little of this salt; boiling water is capable of dissolving about $\frac{1}{100}$ th part of its weight of it. It is insoluble in alcohol.

It is composed of 43 parts of lime, 50 of acid, and 7 of water.

When exposed to the air it dries and falls into powder.

When exposed to a moderate heat it melts and swells up: when placed on burning coals, or when heated in close vessels, the acid is decomposed and volatilized, and the lime remains pure.

When sulphuric acid is poured into a solution of this salt, it produces an insoluble precipitate; nitric and muriatic acids precipitate the camphoric acid.

It is decomposed by compound affinity by

Carbonat of potass,
Nitrat of barytes,
Muriat of alumina,
Sulphat of alumina,
Phosphat of soda *.

* *Bouillon*

6. Camphorat of magnesia. This salt may be prepared by pouring water on carbonat of magnesia, and then adding crystallized camphoric acid: heat is then applied, the solution is filtrated, and evaporated to dryness.

The salt obtained is dissolved in hot water, passed through a filter, and evaporated by means of a moderate heat till a pellicle forms on the surface of the solution. On cooling, the salt is deposited in thin plates. The second solution is to remove any excess of magnesia that may happen to be present.

This salt does not crystallize. It is white, opaque, and has a bitter taste.

It is scarcely more soluble in water than camphorat of lime.

Alcohol has no action on it while cold, but when hot it dissolves the acid and leaves the magnesia; and the acid precipitates again as the alcohol cools.

When exposed to the air it dries and becomes covered with a little powder; but this effect is produced slowly, and only in a warm place.

When this salt is placed on burning coals, the acid is volatilized, and the magnesia remains pure. Before the blow-pipe it burns like the other camphorats with a blue flame.

The nitrats, muriats, and sulphats, do not completely decompose this salt, if we except the nitrat of lime and muriat of alumina †.

† *Ibid.*

829

Camphorat
of alumina.

7. Camphorat of alumina. To prepare this salt, alumina, precipitated by means of ammonia, and well washed, is to be mixed with water, and crystals of camphoric acid added. The mixture is then to be heated, filtered, and concentrated by evaporation.

This salt is a white powder, of an acid bitterish taste, leaving on the tongue, like most of the aluminous salts, a sensation of astringency.

Water at the temperature of 60° dissolves about $\frac{1}{100}$ th part of its weight of this salt. Boiling water dissolves it

Suberats. it in considerable quantities; but it precipitates again as the solution cools.

Alcohol, while cold, dissolves it very sparingly; but when hot it dissolves a considerable quantity of it, which precipitates also as the solution cools.

This salt undergoes very little alteration in the air; but it rather parts with than attracts moisture.

Heat volatilizes the acid; and when the salt is thrown on burning coals it burns with a blue flame.

It is decomposed by the nitrats of lime and barytes*.

* Bouillon
La Grange,
Ann. de
Chim. xxvii.
34.

SECT. XXII. Of Suberats.

THE salts formed by the suberic acid have obtained the appellation of *suberats*. They have hitherto been examined only by Bouillon la Grange.

1. Suberat of potafs.—This salt ought to be formed by means of crystallized carbonat of potafs.

It crystallizes in prisms, having four unequal sides. It has a bitter saltish taste, and it reddens vegetable blues. It is very soluble in water. Caloric melts it, and at last volatilizes the acid.

It is decomposed by most of the metallic salts, and by sulphat of alumina, muriat of alumina, and of lime; nitrat of alumina and of lime; and phosphat of alumina †.

† Id. ibid.
xxiii. 52.
831
Suberat of
soda.

2. Suberat of soda.—This salt does not crystallize. It reddens the tincture of turnsole. Its taste is slightly bitter. It is very soluble in water and in alcohol. It attracts moisture from the air. Caloric produces the same effect on it that it does on suberat of potafs.

It is decomposed by the calcareous, aluminous, and magnesian salts ‡.

‡ Id. ibid.
p. 53.
832
Suberat of
ammonia.

3. Suberat of ammonia.—This salt crystallizes in parallelepipeds. Its taste is saltish, and it leaves an impression of bitterness: It reddens vegetable blues.

It is very soluble in water. It attracts moisture from the air. When placed upon burning coals, it loses its water of crystallization, and swells up; and before the blow-pipe it evaporates entirely.

It is decomposed by the aluminous and magnesian salts §.

§ Id. ibid.
p. 55.
833
Suberat of
barytes.

4. Suberat of barytes.—This salt does not crystallize. Heat makes it swell up, and melts it. It is scarcely soluble in water except there be an excess of acid.

It is decomposed by most of the neutral salts, except the barytic salts and the fluat of lime ||.

|| Id. ibid.
p. 52.
834
Suberat of
lime.

5. Suberat of lime.—This salt does not crystallize. It is perfectly white: It has a saltish taste: It does not redden the tincture of turnsole.

It is very sparingly soluble in water except when hot; and as the solution cools most of the salt precipitates again.

When placed upon burning coals it swells up, the acid is decomposed, and there remains only the lime in the state of powder.

It is decomposed by

- The muriat of alumina,
- The carbonats of potafs and soda,
- The fluat of magnesia,
- The phosphats of alumina and soda,
- The borat of potafs,
- All the metallic solutions ¶.

¶ Id. ibid.
p. 54.
835
Suberat of
magnesia.

6. Suberat of magnesia.—This salt is in the form of a powder. It reddens the tincture of turnsole. It has a

bitter taste: It is soluble in water, and attracts some moisture when exposed to the air.

Prussiat.

When heated it swells up and melts: before the blow-pipe the acid is decomposed, and the magnesia remains in a state of purity.

It is decomposed by

- Muriat of alumina,
- Nitrat of lime and alumina,
- Borat of potafs,
- Fluat of soda,
- Phosphat of alumina*.

* Bouillon
La Grange,
Ann. de
Chim. xxiii.
55.

7. Suberat of alumina.—This salt does not crystallize. When its solution is evaporated by a moderate heat in a wide vessel, the salt obtained is of a yellow colour, transparent, having a styptic taste, and leaving an impression of bitterness on the tongue. When too much heat is employed it melts and blackens. It reddens the tincture of turnsole, and attracts moisture from the air. Before the blow-pipe it swells up, the acid is volatilized and decomposed, and nothing remains but the alumina.

It is decomposed by

- The carbonats of potafs and soda,
- The sulphat of iron,
- The muriat of iron,
- The nitrats of silver, mercury, and lead †.

† Id. ibid.
836
Suberat of
alumina.
† Id. ibid.
p. 57.

Suberic acid forms also compounds with the oxides of silver, mercury, lead, copper, tin, iron, bismuth, arsenic, cobalt, zinc, antimony, manganese, and molybdenum; most of which are incrySTALLIZABLE, and have an excess of acid ‡.

SECT. XXIII. Of Prussiat.

THE compounds into which the prussic acid enters are called *Prussiat*.

These substances, the most important of which are triple salts, have something very peculiar in their affinities. The prussic acid appears to have a stronger affinity for alkalies and earths than for metals, at least these substances are capable of decomposing metallic prussiat; yet acids scarcely decompose the metallic prussiat, while the weakest acid known decomposes the prussiat of alkalies and earths. These phenomena have not yet been satisfactorily accounted for.

1. Prussiat of potafs. } These salts were first ob-
2. Prussiat of soda. } tained pure by Mr Scheele. They are soluble in water; but they are of little use, as mere exposure to the air decomposes them.

837
Alkaline
prussiat.

3. Prussiat of ammonia.—This salt has the smell of ammonia. It is very volatile and as easily decomposed as the other two.

4. Prussiat of lime.—This salt is soluble in water. It is also decomposed by exposure to the air.

838
Earthy
prussiat.

5. Prussiat of barytes. } These salts are also so-
6. Prussiat of magnesia. } luble in water, and decomposed by all acids.

Prussic acid does not combine with alumina.

7. Prussiat of iron, or Prussian blue.—This substance is composed, as Mr Proust has shewn, of the prussic acid and brown oxide of iron. With the green oxide the prussic acid forms a white compound, which, however, becomes gradually blue when exposed to the atmosphere, because the oxide absorbs oxygen, and is converted into brown oxide §.

839
Prussian
blue.

Prussiat of iron is a deep blue coloured powder. It is

§ Nicol-
son's Jour.
i. 453.

Prussiat.

is insoluble in water, and scarcely soluble in acids. It is composed, according to the most accurate experiments hitherto made, of equal parts of oxide of iron and prussic acid. It is not affected by exposure to the air. Heat decomposes it by destroying the acid, and the oxide of iron remains behind.

The Prussian blue of commerce, besides other impurities, contains mixed with it a great quantity of alumina. Its use as a pigment, and the attempts which have been made to introduce it as a dye, are well known.

Prussiat of iron may also exist in another state: It may have a superabundance of oxide; its colour is then more or less yellow. To this state it may be reduced by digesting it with alkalies or any of the alkaline earths. These substances deprive it of part of its acid, but not of the whole.

This yellow prussiat is soluble in acids.

840
Affinities
of the prus-
sic acid ex-
plained.

Were we to attempt an explanation of this, and the other phenomena which the prussic acid displays in its combinations, we would conjecture, that this yellow prussiat is the substance formed by the direct combination of brown oxide of iron and prussic acid, and that the blue prussiat is formed of the yellow prussiat combined as an integrant with prussic acid: That the affinity between the prussic acid and oxide of iron is much stronger than that between yellow prussiat of iron and prussic acid; that therefore alkalies and earths have a stronger affinity for prussic acid than the yellow prussiat has, but a much weaker affinity than oxide of iron, and perhaps every other oxide;—hence the apparent superiority of alkalies and earths in some cases, while in others they appear very inferior. We would suppose, then, that the prussic acid has a much stronger affinity for oxide of iron, and perhaps for all other oxides, than for other bodies; that the prussiats, thus formed, are capable of combining with prussic acid; but that their affinity for it is much less than that of the alkalies and earths. This conjecture is supported by all the phenomena at present known; it would remove all the apparent anomalies which the combinations of this singular acid present, and reduce the whole of them under the known laws of affinity.

841
Properties
of Prussian
alkali,

8. Prussiat of potash and iron, commonly called *Prussian alkali*, or *Prussian test*. This substance is a triple salt, composed of prussic acid, potash, and oxide of iron combined together. To chemists and mineralogists it is one of the most important instruments ever invented; as, when properly prepared, it is capable of indicating whether any metallic substance (platinum excepted) be present in any solution whatever, and even of pointing out the particular metal, and of ascertaining its quantity: This it does by means of a compound affinity, which, after what has been said above, may be easily understood. The Prussian alkali may be conceived to be a combination of two substances, prussiat of potash and blue prussiat of iron. Now every metallic oxide has a stronger affinity for prussic acid than potash has (and, in fact, seems to have a stronger affinity for it than for any other substance). If, therefore, there happen to be any oxide in the solution, it immediately seizes the prussic acid with which the potash is combined, and by that means decomposes the triple salt. A prussiat of metals are insoluble, it is precipitated; and it indicates by its colour the particular metal, and by its

weight the quantity of metal that happens to be present. At the same time the blue prussiat of iron is also precipitated, and its weight must be deducted from the quantity of the precipitate.

Prussiats.

In order to be certain of the accuracy of these results, it is necessary to have a Prussian alkali perfectly pure, and to be certain before hand of the quantity, or rather of the proportions of its ingredients. To obtain a test of this kind has been the object of chemists ever since the discoveries of Macquer pointed out its importance. It is to the use of impure tests that a great part of the contradictory results of mineralogical analyses by different chemists is to be ascribed.

There are two * ways in which this test may be rendered impure, besides the introduction of foreign ingredients, which we do not mention, because it is obvious that it must be guarded against. 1. There may be a superabundance of alkali present, or, which is the same thing, there may be mixed with the Prussian test a quantity of pure alkali; or, 2. There may be contained in it a quantity of yellow prussiat of iron, for which prussiat of potash has also a considerable affinity.

If the Prussian test contain a superabundance of alkali, two inconveniences follow. This superabundant quantity will precipitate those earthy salts which are liable to contain an excess of acid, and which are only soluble by that excess: Hence alumina and barytes will be precipitated. It is to the use of impure tests of this kind that we owe the opinion, that barytes and alumina are precipitated by the Prussian alkali, and the consequent theories of the metallic nature of these earths. This mistake was first corrected, we believe, by Mr Klaproth.

Another inconvenience arising from the superabundance of alkali in the Prussian test is, that it gradually decomposes the blue prussiat which the test contains, and converts it into yellow prussiat. In what manner it does this will be understood, after what has been said, without any explanation.

On the other hand, when the Prussian alkali contains a quantity of yellow prussiat of iron, as great inconveniences follow. This yellow prussiat has an affinity for prussic acid, which, though inferior to that of the potash, is still considerable; and, on the other hand, the potash has a stronger affinity for every other acid than for the prussic. When, therefore, the test is exposed to the air, the carbonic acid, which the atmosphere always contains, assisted by the affinity between the yellow prussiat and the prussic acid, decomposes the prussiat of potash in the test; and the yellow prussiat is precipitated in the form of Prussian blue: And every other acid produces the same effect. A test of this kind, therefore, would indicate the presence of iron in every mixture which contains an acid (for a precipitation of Prussian blue would appear); and could not, therefore, be trusted to with any confidence.

We will not attempt to describe the various methods which different chemists have adopted of preparing this test; but shall satisfy ourselves with describing the method of Klaproth, which answers the purpose completely. This we shall do nearly in the words of Mr Kirwan.

Prepare a pure potash, by gradually projecting into a large crucible heated to whiteness a mixture of equal parts of purified nitre and crystals of tartar; when the whole

Prussiate. is injected, let it be kept at a white heat for half an hour, to burn off the coal.

Detach the alkali thus obtained from the crucible, reduce it to powder, spread it on a muffle, and expose it to a white heat for half an hour.

Dissolve it in six times its weight of water, and filter the solution while warm.

Pour this solution into a glass receiver, placed in a sand furnace, heated to 170° or 180°, and then gradually add the best Prussian blue in powder, injecting new portions according as the former becomes grey, and supplying water as fast as it evaporates; continue until the added portions are no longer discoloured, then increase the heat to 212° for half an hour.

Filter the ley thus obtained, and saturate it with sulphuric acid moderately diluted; a precipitate will appear; when this ceases, filter off the whole, and wash the precipitate.

Evaporate the filtered liquor to about one quarter, and set it by to crystallize: after a few days, yellowish crystals of a cubic or quadrangular form will be found mixed with some sulphat of potash and oxide of iron; pick out the yellowish crystals, lay them on blotting paper, and redissolve them in four times their weight of cold water, to exclude the sulphat of potash.

7. Essay a few drops of this solution with barytic water, to see whether it contains any sulphuric acid, and add some barytic water to the remainder if necessary: filter off the solution from the sulphat of barytes, which will have precipitated, and set it by to crystallize for a few days; that the barytes, if any should remain, may be precipitated. If the crystals now obtained be of a pale yellow colour, and discover no bluish streaks when sprinkled over with muriatic acid, they are fit for use; but if they still discover bluish or green streaks, the solutions and crystallizations must be repeated.

These crystals must be kept in a well-stopped bottle, which to preserve them from the air should be filled with alcohol, as they are insoluble in it.

Before they are used, the quantity of iron they contain should be ascertained, by heating 100 grains to redness for half an hour in an open crucible: the prussic acid will be consumed, and the iron will remain in the state of a reddish brown magnetic oxide, which should be weighed and noted: This oxide is half the weight of the Prussian blue afforded by the Prussian alkali; its weight must therefore be subtracted from that of metallic precipitates formed by this test. Hence the weight of the crystals, in a given quantity of the solution, should be noted, that the quantity employed in precipitation may be known. Care must be taken to continue the calcination till the oxide of iron becomes brown; for while

it is black it weighs considerably more than it should*.

9. Prussiat of soda and iron. The only discernible difference between this salt and the last is, that it crystallizes differently †.

10. Prussiat of ammonia and iron. This triple salt has also been employed as a test; but it is not so easy to obtain it in a state of purity as the other two. It was discovered by Macquer, and first recommended by Meyer.

It forms flat hexangular crystals, soluble in water, and deliquesces in the air. Heat decomposes it like the other prussiates ‡.

We shall not give any description of the triple salts

formed by digesting the alkaline earths on prussiat of iron; they are sufficiently known, and are not of any use except as tests; and in that respect they are inferior to that above described. They are all soluble in water, and are most of them capable of crystallizing.

11. Prussiat of mercury. This salt, which was first formed by Scheele, is composed of the prussic acid combined with the red oxide of mercury. It may be formed by boiling the red oxide of mercury with Prussian blue. It crystallizes in tetrahedral prisms, terminated by quadrangular pyramids, the sides of which correspond with the angles of the prism.

This salt is capable of combining with sulphuric and muriatic acids, and forming triple salts, which have not yet been examined*.

SECT. XXIV. Of Formats.

THE compounds into which the formic acid enters are called *formats*. We shall not describe them, as little has been added to the account already given in the Appendix to the article CHEMISTRY in the Encyclopædia.

SECT. XXV. Of Sebats.

THE compounds into which the sebatic acid enters are called *sebats*. For our knowledge of this class of salts we are chiefly indebted to the celebrated Crell, who published a dissertation on the sebatic acid and its combinations in the Philosophical Transactions for 1780 and 1782.

1. *Sebat of potash*. This salt is of a white colour. Its crystals are quadrangular pyramids, of which two opposite sides are narrower than the others. It has a sharp saline taste like muriat of ammonia, but milder. It is soluble in water, insoluble in alcohol, and does not deliquesce when exposed to the air. Heat decomposes it.

2. *Sebat of soda*. This salt is white. Its crystals are pyramids, with three or four sides: a very moderate heat melts them.

3. *Sebat of ammonia*. This salt in taste and solubility resembles muriat of ammonia, but it differs from it in not being capable of subliming iron.

4. *Sebat of lime*. The crystals of this salt are hexagons, terminated by a plane surface: they have a sharp acrid taste; are very soluble in water, but not in alcohol: they do not deliquesce.

5. *Sebat of magnesia*. A gummy, saline, uncrystallizable mass.

6. *Sebat of alumina*. A gummy saline mass, which does not crystallize, and has an austere astringent taste.

7. *Sebat of iron*. Needle-shaped crystals, which deliquesce.

8. *Sebat of lead*. Needle-shaped crystals, very soluble in water.

9. *Sebat of tin*. A white deliquescent salt.

10. *Sebat of copper*. This salt is capable of crystallizing, but is very deliquescent.

11. *Sebat of antimony*. A crystallizable salt, which does not deliquesce.

12. *Sebat of arsenic*. Small crystals.

13. *Sebat of mercury*. A white powder, very difficultly soluble in water.

14. *Sebat of gold*. Yellow crystals.

15. *Sebat of platinum*. Brownish yellow crystals.

The bombats or compounds which the bombic acid forms are still unknown.

Sebats.

815
Prussiat of mercury.

* *Berthollet.*

846

bats.

847

Earthy *sebats.*

848

Metallic *sebats.*

* *Kirwan's Mineral.* 2. 494.

† *Berthollet.* 844
Prussiat of ammonia and iron.

‡ *Woulfe, Journ. de Phys.* xxxiv. 301.

SECT. XXVI. *Of Arseniats.*

THE compounds formed by the combination of the arsenic acid with bases are called *arseniats*. This class of salts was first discovered by Macquer; but little accurate was known concerning it till Scheele made known the arsenic acid.

An abstract of Scheele's experiments has been given in the article CHEMISTRY, *Encycl.*

To his description of arseniats several additions might be made, but not of sufficient consequence to warrant a repetition of what has been given in that article; and without such a repetition these additions would scarcely be intelligible.

SECT. XXVII. *Of Metallic Acid Salts.*

IT has been conjectured that all metals may be converted into acids by combining them with a sufficient quantity of oxygen. This conjecture has been verified in a considerable number of instances. We have seen the arsenic acid, the tungstic acid, the molybdic acid, and the new metallic acid of Vauquelin. Berthollet has discovered that platinum becomes an acid; and the same thing has been ascertained with regard to tin. Even those metallic oxides which do not possess many of the characters of acids are capable of combining with alkalies and earths, and of forming peculiar neutral salts. These oxides, therefore, perform the office of acids; and consequently must be considered as partaking of their nature, or rather as a kind of intermediate substances between acids and those bodies which unite only with acids.

Some of these neutral salts we shall proceed to enumerate.

1. Aurat of ammonia, or fulminating gold. This salt is composed of the oxide of gold and ammonia. This compound may be formed by precipitating gold from nitro-muriatic acid by ammonia. The precipitate is fulminating gold. Bergman was the first who clearly demonstrated that this powder is composed of oxide of gold and ammonia. When heated a little above the boiling temperature it explodes with astonishing violence. Chemists had made many attempts to explain the cause of this phenomenon, but without success, till Mr Berthollet discovered the composition of ammonia. After making that discovery, he proved, by a number of delicate and hazardous experiments, that during the fulmination the ammonia is decomposed, that its hydrogen combines with the oxygen of the oxide and forms water, while the azot flies off in a gaseous form, and occasions the explosion.

2. Argentat of ammonia, or fulminating silver. This substance was discovered by Mr Berthollet. It may be formed by dissolving oxide of silver in ammonia. It is a black powder. It possesses the fulminating property much more powerfully than the last described substance. The slightest friction makes it explode with violence. This property, as Mr Berthollet has proved*, is owing to the same decomposition of ammonia and formation of water that causes the explosion of fulminating gold.

If a small retort be filled with the liquor from which the fulminating silver has been precipitated, and be made to boil, some azot is disengaged, and small opaque crystals are formed consisting of the same substance; which explode when touched, though they be covered with

water. Nitrat and muriat of barytes precipitate silver from this salt.

3. Mercuriat of lime. Oxide of mercury boiled with lime-water forms, by evaporation, small transparent yellow crystals*.

4. Mercuriat of ammonia. Oxide of mercury dissolves in ammonia in large quantity, and by evaporation furnishes a white salt †.

5. Cuprat of ammonia. Oxide of copper dissolves in ammonia. Mr Sage has described its crystallization. It is decomposed by lime and potash, and cuprat of lime and potash are formed.

6. Stannat of gold. When gold is precipitated by tin it unites with it. Vogel and Beaumé first observed that the precipitate, which is purple, contained tin.

7. Plumbat of lime. Lime-water boiled on the red oxide of lead dissolved in it. This solution, evaporated in a retort, gave very small transparent crystals, forming prismatic colours, and not more soluble in water than lime. It is decomposed by all the sulphats of alkalies and by sulphurated hydrogen gas. The sulphuric and muriatic acids precipitate the lead. It blackens wool, the nails, the hair, white of eggs; but it does not affect the colour of silk, the skin, the yoke of eggs, nor animal oil. It is the lead which is precipitated on these coloured substances in the state of oxide; for all acids can dissolve it. The simple mixture of lime and oxide of lead blackens these substances; a proof that the salt is easily formed †.

8. Zincat of ammonia. De Cassone has published a great number of experiments on the property which ammonia has of dissolving oxide of zinc. Lime-water and potash also dissolve it §.

9. Antimoniat of potash. When antimony is detonated with nitre in a crucible, part of its oxide unites with the potash of the nitre ||.

CHAP. III. *Of Hydrosulphurets.*

SULPHURATED hydrogen gas, which has been described in the first part of this article, possesses almost all the properties of acids. It combines with water, and the solution gives a red colour to vegetable blues. It decomposes soaps and sulphurets, and is capable of combining with alkalies, earths, and metallic oxides, and of forming compounds, to which Mr Berthollet, to whom we are indebted for discovering them, has given the name of *hydrosulphurets* ¶.

Before giving any account of these compounds, which we shall do from the paper of Berthollet just quoted, we beg leave to make a few previous observations, in order to rectify some inaccuracies into which we have fallen from not being acquainted with the experiments of that philosopher.

Sulphur is capable of combining with alkalies, earths, metals, and metallic oxides, and forming the compounds known by the name of *sulphurets*. The alkaline, earthy, and even some of the metallic sulphurets, can only exist in a state of dryness: the instant they are moistened with water, a quantity of sulphurated hydrogen gas is formed, which combines with the sulphuret, and forms a new compound. To these triple compounds Mr Berthollet has given the name of *hydrogenous sulphurets*. All solutions of sulphurets in water are in fact hydrogenous sulphurets. Were it not for the formation and combination of sulphurated hydrogen, the alkaline sulphurets would

Hydrosulphurets.

851

Mercuriat of nitre and of ammonia.

† *Id. ibid.*† *Lavoisier, ibid.*

852 Cuprat of ammonia.

853

Stannat of gold.

854

Plumbat of lime.

† *Berthollet, Ann. de Chim. i. 37.*

855

Zincat of ammonia.

§ *Id. ibid.*

p. 42.

856

Antimoniat of potash.

|| *Id. ibid.*

857

Properties of sulphurated hydrogen gas.

¶ *Ann. de Chim. xxv. 233.*

858

Remarks on sulphurets.

849
Fulminating gold.850
Fulminating silver.* *Berthollet, Ann. de Chim. i.*

Hydrofulphurets. would be completely decomposed by water, and their sulphur precipitated; for water has a stronger affinity for the alkalies than sulphur has. This Berthollet proved by the following experiment: To a solution of sulphuret of potash in water (that is, to hydrogenous sulphuret of potash), a quantity of oxy-muriatic acid saturated with potash was added, and the sulphur was immediately precipitated. In this experiment the sulphurated hydrogen was destroyed by the oxygen of the oxy-muriatic acid; and the precipitation of the sulphur shews that its affinity for potash was not sufficient to keep it dissolved, or, which is the same thing, that its affinity for potash was inferior to that of water.

859
Hydrogenous sulphuret of mercury.

The substance which we described in Part I. chap. iii. sect. 4. of this article, under the name of *Black Sulphuret of Mercury*, is a hydrogenous sulphuret of mercury, and therefore differs from the red sulphuret of mercury or cinnabar by containing a quantity of sulphurated hydrogen. Potash has a stronger affinity for this last substance than the sulphuret; potash therefore, by the assistance of heat, deprives the black or hydrogenous sulphuret of its sulphurated hydrogen, and reduces it to the state of red sulphuret. This explains the method of forming cinnabar described in the section above referred to, and points out a much easier process for obtaining that useful pigment.

860
Method of forming hydrofulphurets.

We shall now proceed to the method of forming the hydrofulphurets. Berthollet obtained sulphurated hydrogen gas from sulphuret of iron in the usual manner, by means of sulphuric acid. It was made to pass thro' a vessel filled with water before it entered that in which the combination was to take place. By this method a solution of potash was impregnated with sulphurated hydrogen; and in order to be certain of saturating the alkali completely, the gas was added in excess, and the excess was afterwards driven off by means of heat. By this method hydrofulphurets of potash, soda, and ammonia, may be formed.

In order to form hydrofulphuret of lime, that earth was mixed with distilled water, and sulphurated hydrogen gas passed into this mixture till a sufficient quantity of hydrofulphuret was judged to be formed; the liquid, which contained it in solution, was poured off the undissolved lime, and saturated to excess with sulphurated hydrogen, and this excess was afterwards driven off by means of heat.

Hydrofulphuret of magnesia may be formed by dissolving magnesia in water impregnated with sulphurated hydrogen gas.

If a solution of sulphuret of barytes in water, or, more properly, if hydrogenous sulphuret of barytes be evaporated, a great number of confused crystals are formed; if these be separated quickly by filtration, and placed upon blotting paper to dry, a white crystalline substance is obtained, which is hydrofulphuret of barytes.

861
Affinities of sulphurated hydrogen.

The affinities of the alkalies and earths for sulphurated hydrogen appear, from the experiments of Berthollet, to be as follows:

Barytes,
Potash,
Soda,
Lime,
Ammonia,

Magnesia,
Jargonia.

Almost all the metallic oxides have a stronger affinity for sulphurated hydrogen than the earths have.

When the hydrofulphurats are prepared with the necessary precautions to prevent the contact of atmospheric air, they are colourless, but the action of the air renders them yellow.

If they be decomposed while they are colourless, by pouring upon them sulphuric acid, muriatic acid, or any other acid which does not act upon hydrogen, the sulphurated hydrogen gas exhales without the deposition of a single particle of sulphur; but if the hydrofulphuret has become yellow, some sulphur is always deposited during its decomposition, and the quantity of sulphur is proportional to the deepness of the colour.

The yellow colour, therefore, which hydrofulphurets acquire by exposure to the atmosphere is owing to a commencement of decomposition. Part of the hydrogen of the sulphurated hydrogen abandons the sulphur, combines with the oxygen of the atmosphere, and forms water. By degrees, however, a portion of the sulphur is also converted into an acid; and when the proportion of sulphurated hydrogen is diminished, and that of the sulphur increased to a certain point, the sulphur and the hydrogen combine equally with oxygen.

If sulphuric or muriatic acids be poured upon a hydrofulphuret after it has been for some time exposed to the air, a quantity of sulphurated hydrogen gas exhales, sulphur is deposited, and after an interval of time sulphurous acid is disengaged. It is therefore sulphurous, and not sulphuric acid, which is formed while the hydrofulphuret spontaneously absorbs oxygen. This acid, however, is not perceptible till after a certain interval of time when separated from the hydrofulphuret by means of an acid; because as long as it meets with sulphurated hydrogen a reciprocal decomposition takes place. The oxygen of the acid combines with the hydrogen of the gas, and the sulphur of both is precipitated.

Sulphurated hydrogen is capable of combining with several of the metals, mercury, for instance, and silver: it combines with the greater number of the metallic oxides, and forms hydrofulphurets, on which the alkalies have no action at the temperature of the atmosphere: But concentrated acids combine with the oxides of these hydrofulphurets, and separate the sulphurated hydrogen in the form of gas.

In the greater number of these metallic oxide hydrofulphurets, the tendency which oxygen and hydrogen have to combine occasions a partial decomposition of the sulphurated hydrogen, and brings the oxides nearer to the metallic state. In some of these hydrofulphurets part of the sulphur also combines with oxygen, and forms sulphuric acid.

The alkaline hydrofulphurets precipitate all the metals from their combination with acids; they are therefore very valuable tests of the presence of metals in any solution, as they do not precipitate any of the earths except alumina and jargonia. The following Table exhibits a view of the effect of hydrofulphuret of potash, hydrogenous sulphuret of potash, and water impregnated with sulphurated hydrogen gas, upon various metallic solutions.

Metallic

Hydrofulphuret.

862
Properties of hydrofulphurets.

863
Metallic hydrofulphurets.

Hydrofulphurets.

Hydrofulphurets.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potass.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrofulphuret of Potass.
Green sulphat of iron.	A black precipitate, which becomes yellow by the contact of the air.		A black precipitate. The potass separated.
Red oxide of iron.		Becomes black. The liquor remains very deep coloured if there be an excess of sulphurated hydrogen.	Becomes black.
Sulphat of zinc.	A white precipitate.	A white precipitate.	A white precipitate.
Acetite of lead.	A white precipitate, which by an addition becomes black.	A black precipitate.	A black precipitate.
Red oxide of lead.		Becomes black.	The potass separated.
Nitrat of bismuth.		A black precipitate.	A black precipitate.
Oxide of bismuth.		Becomes black.	
Nitrat of silver.	A black precipitate.	A black precipitate.	A black precipitate.
Sulphat of copper.	A brown precipitate.	A black precipitate.	A black precipitate.
Green oxide of copper.		Becomes black.	Separation of the potass.
Nitrat of mercury.	In a great deal of water, a brown colour.	A brownish black precipitate.	A brownish black precipitate.
Oxy-muriat of mercury.	A white precipitate, which becomes black by addition.	A white precipitate, becoming black by an addition.	White, becomes black by addition.
Red oxide of mercury.		Blackish.	A heat produced which caused the hydrofulphuret to boil. The alkali separated (A).
Muriat of tin.			A black precipitate.
Oxy-muriat of tin.	A precipitation of sulphur, and of the oxide.	No change.	A precipitate of white oxide of tin, and a disengagement of sulphurated hydrogen gas.
White oxide of tin.		No change.	Disengagement of sulphurated hydrogen gas.
Sulphat of manganese.		No change.	A white precipitate.
Black oxide of manganese.		The odour disappears. An excess of the water dissolves the oxide.	Ammonia disengaged. Heat. The liquor boils (A).
Nitrat of antimony.			A reddish orange precipitate.
Tartrite of antimony.	A yellow orange precipitate.	An orange colour, but no precipitate.	An orange red precipitate, redissolved by an excess of hydrofulphuret.
White oxide of antimony.		Becomes yellow after some seconds.	The liquor loses its colour (A).

Metallic

(A) In these, hydrofulphuret of ammonia was used instead of hydrofulphuret of potass.

Metallic Solutions.	Solution of Hydrogenous Sulphuret of Potash.	Water impregnated with Sulphurated Hydrogen Gas.	Hydrosulphuret of Potash.
Oxide of antimony sublimed.		Scarcely changes colour.	
Solution of oxide of arsenic.	Sulphuret decomposed as by an acid.	Becomes somewhat muddy, and of a yellow colour.	A yellow colour, but no precipitate.
Sulphat of titanium.			A precipitate of a deep green.
Molybdic acid.		A brown precipitate.	A brown precipitate.

CHAP. IV. Of CRYSTALLIZATION.

864
Crystals

THE word *crystal*, in its strict and proper sense, signifies a transparent body possessed of a regular figure. But it is now used to denote a body which has assumed a regular figure whether it be transparent or not. *Crystallization* is the *act* by which this regular figure is formed.

As the greater number of crystals belong to the class of neutral salts, it may not be improper, before we conclude this part of the article, to make a few observations on the phenomena of crystallization.

As crystallization is confessedly nothing else than the regular arrangement of the particles of bodies, it is evident that before it can take place the particles of the body to be crystallized must be at some distance from each other, and that they must be at liberty to obey the laws of attraction. They may be put into this situation by three methods, solution, suspension, and fusion.

865
Formed by solution,

1. Solution is the common method of crystallizing salts. They are dissolved in water: The water is slowly evaporated, the saline particles gradually approach each other, combine together, and form small crystals; which become constantly larger by the addition of other particles till at last they fall by their gravity to the bottom of the vessel. It ought to be remarked, however, that there are two kinds of solution, each of which presents different phenomena of crystallization. Some salts dissolve in very small proportions in cold water, but are very soluble in hot water; that is to say, water at the common temperature has little effect upon them, but water combined with caloric dissolves them readily. When hot water saturated with any of these salts cools, it becomes incapable of holding them in solution: the consequence of which is, that the saline particles gradually approach each other and crystallize. Sulphat of soda is a salt of this kind. To crystallize such salts, nothing more is necessary than to saturate hot water with them, and set it by to cool. But were we to attempt to crystallize them by evaporating the hot water, we should not succeed; nothing would be procured but a shapeless mass. Many of the salts which follow this law of crystallization combine with a great deal of water; or, which is the same thing, many crystals formed in this manner contain a great deal of water of crystallization.

There are other salts again which are nearly equally soluble in hot and cold water; common salt for instance. It is evident that such salts cannot be crystallized by

cooling; but they crystallize very well by evaporating their solution while hot. These salts generally contain but little water of crystallization.

2. It appears, too, that some substances are capable of assuming a crystalline form merely by having their particles suspended in water, without any regular solution; at least it is not easy, on any other supposition, to explain the crystallizations of carbonate of lime sometimes deposited by waters that run over quantities of that mineral.

3. There are many substances, however, neither soluble in water, nor capable of being so minutely divided as to continue long suspended in that fluid; and which, notwithstanding, are capable of assuming a crystalline form. This is the case with the metals, with glass, and some other bodies. The method employed to crystallize them is *fusion*, which is a solution by means of caloric. By this method the particles are separated from one another; and if the cooling goes on gradually, they are at liberty to arrange themselves in regular crystals. There are many substances, however, which it has been hitherto impossible to reduce to a crystalline form, either by these or any other method. Whether this be owing to the nature of these bodies themselves, or to our ignorance of the laws by which crystals are formed, as is much more likely, cannot be determined.

The phenomena of crystallization seem to have attracted but little of the attention of the ancient philosophers. Their theory indeed, that the elements of bodies possess certain regular geometrical figures, may have been suggested by these phenomena; but we are ignorant of their having made any regular attempt to explain them. The schoolmen ascribed the regular figure of crystals to their substantial forms, without giving themselves much trouble about explaining the meaning of the term. This notion was attacked by Boyle; who proved that crystals were formed by the mere aggregation of particles*. But it still remained to explain, why that aggregation took place? and why the particles united in such a manner as to form regular figures? These questions were answered by Newton. According to him, the aggregation is produced by the attraction which he had proved to exist between the particles of all bodies, and which acts as soon as these particles are brought within a certain distance of each other by the evaporation of the liquid in which they are dissolved. The regularity of their figures he explained by supposing, that while in a state of solution they were arranged in the liquid in regular rank and file; the consequence

866
Suspension,867
And fusion.868
Crystallization explained.

* Treatise on the Origin of Forms and Qualities.

CrySTALLIZATION. sequence of which, as they are acted upon by a power which at equal distances is equal, at unequal distances unequal, will be crystals of determinate figures*.

* *Optics*, p. 363. This explanation, which is worthy of Newton, is now universally admitted as the true one, and has contributed much towards elucidating this important part of chemistry.

Still, however, there remain various phenomena relating to crystallization, which it is no easy matter to explain.

869
Salts do not easily crystallize in close vessels,

It has been observed, that those salts which crystallize upon cooling, do not assume a crystalline form so readily if they are allowed to cool in close vessels. If a saturated solution of sulphat of soda, for instance, in hot water be put into a phial, corked up closely, and allowed to cool without being moved, no crystals are formed at all; but the moment the glass is opened, the salt crystallizes with such rapidity that the whole of the solution in a manner becomes solid. This phenomenon has been explained by supposing that there is an affinity between the salt and caloric, and that while the caloric continues combined with it the salt does not crystallize; that the caloric does not leave the salt so readily when external air is not admitted, as glass receives it very slowly and parts with it very slowly. In short, the atmospheric air seems to be the agent employed to carry off the caloric; a task for which it is remarkably well fitted, on account of the change of density which it undergoes by every addition of caloric. This is confirmed by the quantity of caloric which always makes its appearance during these sudden crystallizations. This explanation might be put to the test of experiment, by putting two solutions of sulphat of soda in hot water in two similar vessels; one of glass, the other of metal, and both closed in the same manner. If the salt contained in the metallic vessel crystallized, which ought to be the case on account of the great conducting power of metals, while that in the glass vessel remained liquid, this would be a confirmation of the theory, amounting almost to demonstration. On the contrary, if both solutions remained liquid, it would be a proof that the phenomenon was still incompletely understood.

Not only salts, but water itself, which commonly crystallizes at 32° , may be made to exhibit the same phenomenon: it may be cooled much lower than 32° without freezing. This, as Dr Black has completely proved, depends entirely upon the retention of caloric.

871
Variety of forms in crystals accounted for.

If the regular form of crystals depends upon the aggregation of particles, and if during all crystallizations this aggregation goes on in the same manner, why have not all crystals the same form? Some have ascribed these differences to a certain polarity which the particles of bodies are supposed to possess, and which disposes each kind of particles to arrange themselves according to a certain law. Sir Isaac Newton appears rather to have ascribed it to the forms of the particles themselves †; and this seems to be the real solution of the problem. For supposing that all particles have the same form, they must of course possess the same polarity; and therefore every crystal must have the same form. It is impossible, then, to account for the different forms of crystals without supposing that the particles which compose them have also different forms. And if the particles of bodies have different forms, their regular

† *Optics*, p. 375.

aggregation must produce crystals of various shapes; and therefore their polarity, which is merely a supposition founded on this difference in the appearance of crystals, cannot be admitted. Suppose, for instance, that eight cubic particles were regularly arranged in water, and that by the gradual evaporation of the liquid were to approach, and at last to combine, it is evident that the crystal which they would produce would be a cube. Eight six-sided prisms would also produce a six-sided prism; and eight tetrahedrons would form a very different figure.

But it will be asked, if the figure of crystals depends entirely upon the form of the particles that compose them, how comes it that the same substance does not always crystallize in the same way, but presents often such a variety of forms that it is scarcely possible to reckon them? We answer, that these various forms are sometimes owing to variations in the ingredients which compose the integrant particles of any particular body. Alum, for instance, crystallizes in octahedrons; but when a quantity of alumina is added, it crystallizes in cubes; and when there is an excess of alumina, it does not crystallize at all. If the proportion of alumina varies between that which produces octahedrons and what produces cubic crystals, the crystals become figures with fourteen sides; six of which are parallel to those of the cube and eight to those of the octahedron; and according as the proportions approach nearer to those which form cubes or octahedrons, the crystals assume more or less of the form of cubes or octahedrons. What is still more, if a cubic crystal of alum be put into a solution that would afford octahedral crystals, it passes into an octahedron: and, on the other hand, an octahedral crystal put into a solution that would afford cubic crystals, becomes itself a cube*. Now, how difficult a matter it is to proportion the different ingredients with absolute exactness, must appear evident to all.

* *Le Blanc, Ann. de Chim. xiv.*

Another circumstance which contributes much to vary the form of crystals, is the different degree of concentration to which their solution has been reduced, and the rapidity or slowness with which they are formed. For it is too evident to require illustration, that when crystals are deposited very rapidly they must obstruct one another, and mix together so as very much to obscure the natural regularity of their form.

Even the nature of the vessel in which the crystallization is performed is not without some influence.

But, independent of these accidental circumstances, Mr Haüy has shewn that every particular species of crystals has a primitive figure, and that the variations are owing to the different ways in which the particles arrange themselves. Of this theory, which is certainly exceedingly ingenious, and even satisfactory, we shall attempt to give a short view.

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Haüy's theory of crystals.

Happening to take up a hexangular prism of calcareous spar, or carbonat of lime, which had been detached from a group of the same kind of crystals, he observed that a small portion of the crystal was wanting, and that the fracture presented a very smooth surface. Let *abcde fgh* (fig. 8.) be the crystal; the fracture lay obliquely as the trapezium *psui*, and made an angle of 135° , both with the remainder of the base *abcspb* and with *tuef*, the remainder of the side *inef*. Observing that the segment *psutin* thus cut off had for its vertex *in*, one of the edges of the base *abcnib* of the prism, he attempted to detach

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By continuing sections parallel to the former ones, the lateral pentagons diminished in length; and at last the points R, G coinciding with the points Y, Z, the points S, R with the points U, Y, &c. there remained nothing of the lateral pentagons but the triangles YIZ, UXY, &c. (fig. 10.). By continuing the same sections, these triangles at last disappeared, and the prism was converted into the rhomboid *ae* (fig. 11.).

So unexpected a result induced him to make the same attempt upon more of these crystals; and he found that all of them could be reduced to similar rhomboids. He found also, that the crystals of other substances could be reduced in the same manner to certain primitive forms; always the same in the same substances, but every substance having its own peculiar form. The primitive form of fluat lime, for instance, was an octahedron; of sulphat of barytes, a prism with rhomboidal bases; of field-spath, an oblique angled parallelepiped, but not rhomboidal; of adamantine spar, a rhomboid, somewhat acute; of blende, a dodecahedron, with rhomboidal sides; and so on.

These must be considered as the real *primitive forms* of the crystals; the other forms which they often assume may be called *secondary forms*.

The primitive crystals obtained by the above process may be divided by sections parallel to their different sides: all the matter which surrounded this primitive crystal

may also be divided by sections parallel to the sides of the primitive crystal. It follows from this, that the parts detached by means of these sections are similar, and differ from one another only in size, which diminishes in proportion to the length that the division is carried. But the division of the crystals into similar solids has a term, beyond which we should come to the smallest particles of the body, which could not be divided without chemical decomposition. It is probable, therefore, that the form of the integrant particles of a body is the same with the primitive form of its crystals. Here, then, we have a method of discovering the form of the particles of bodies; and if this method could be applied to all substances whatever, it would enable us to ascertain the affinity of all bodies for each other by accurate calculation. It must be allowed that several objections might be made to the conclusions of Mr Haüy; but his theory is, on the whole, so plausible, that it would certainly be worth while to extend it, and apply it to the calculation of affinities as far as it is susceptible of the application. If the crystals obtained by the above process be the primitive forms, it becomes a question of some consequence to determine in what manner the secondary forms are produced.

According to Haüy, all the parts superadded to the primitive crystals, in order to form the secondary crystal, consist of plates, which decrease regularly by the subtraction of one or more rows of integrant particles, in such a manner, that the number of these ranks, and consequently the form of the secondary crystal, may be determined by theory (c).

To explain this, let us suppose that EP (fig. 12.) represents a dodecahedron, terminated by equal and similar rhombs; that this dodecahedron is a secondary crystal, the primitive form of which is a cube: the situation of this cube in the dodecahedron may be conceived from fig. 13. The smaller diagonals DC, CG, GF, FD, of four sides of the dodecahedron, united round the same solid angle L, form the square CDFG. Now there are six solid angles, composed of four plains, to-wit, the angles L, O, E, N, R, P (fig. 12.); and consequently, by making sections through the smaller diagonals of the sides that form these angles, six squares will be made apparent, which are the six sides of the primitive cube, three of which are represented in fig. 13. CDFG, ABCD, BCGH.

This cube being composed of cubic integrant particles, each of the pyramids, LCDFG for instance (fig. 13.) which repose upon its sides, must also, according to the theory, be composed of similar cubic particles. To make this appear, let us suppose that ABFG (fig. 14.) is a cube composed of 729 small cubes: Each of its sides will consist of 81 squares, being the external sides of as many cubic particles, which together constitute the cube. Upon ABCD, one of the sides of this cube, let us apply a square lamina, composed of cubes equal to those of which the primitive crystal consists, but which has on each side a row of cubes less than the outermost layer of the primitive cube. It will of course be composed of 49 cubes, 7 on each side; so that its lower base *onfg* (fig. 15.) will fall exactly on the square marked with the same letters in fig. 14.

Above this lamina let us apply a second *lm pu* (fig. 16.),

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16.), composed of 25 cubes; it will be situated exactly above the square marked with the same letters (fig. 14.) Upon this second let us apply a third lamina $vxyz$ (fig. 17.) consisting only of 9 cubes; so that its base shall rest upon the letters $vxyz$ (fig. 14.). Lastly, on the middle square r let us place the small cube r (fig. 18.), which will represent the last lamina.

It is evident, that by this process a quadrangular pyramid has been formed upon the face ABCD (fig. 14.), the base of which is this face, and the vertex the cube r (fig. 18.). By continuing the same operation on the other five sides of the cube, as many similar pyramids will be formed; which will envelope the cube on every side.

It is evident, however, that the sides of these pyramids will not form continued planes, but that, owing to the gradual diminution of the laminae of the cubes which compose them, these sides will resemble the steps of a stair. We can suppose, however (what must certainly be the case), that the cubes of which the nucleus is formed are exceedingly small, almost imperceptible; that therefore a vast number of laminae are required to form the pyramids, and consequently that the channels which they form are imperceptible. Now DCBE (fig. 19.) being the pyramid resting upon the face ABCD (fig. 14.), and CBOG (fig. 19.) the pyramid applied to the next face BCGH (fig. 14.), if we consider that every thing is uniform from E to O (fig. 19.) in the manner in which the edges of the laminae of superposition (as the Abbé Hauy calls the laminae which compose the pyramids) mutually project beyond each other, it will readily be conceived, that the face CEB of the first pyramid ought to be exactly in the same plane with the face COB of the adjacent pyramid; and that therefore the two faces together will form one rhomb ECOB. But all the sides of the six pyramids amount to 24 triangles similar to CEB; consequently they will form 12 rhombs, and the figure of the whole crystal will be a dodecahedron, similar to that represented in fig. 12. and 13.

If the decrease of the laminae of superposition took place according to a more rapid law, if each lamina had on its circumference two, three, or four rows of cubes less than the inferior lamina—in that case, the pyramids produced being lower, their adjacent faces would no longer form one plane; and therefore the surface of the secondary crystal would consist of 24 isosceles triangles, all inclined towards each other.

In this manner Mr Hauy has shewn, that a variety of secondary crystals are formed, and that their forms vary by means of slight variations in the ratio of the decrement. Dodecahedral sulphuret of iron, for instance, is formed from a cubic nucleus, by the addition of laminae, decreasing, as in the example given above, with this difference, that from every lamina laid upon the face ABCD (fig. 14.) only one row of cubes are subtracted at the sides AD and BC respectively; whereas two rows are subtracted at each of the sides AB and CD. The consequence of this more rapid decrement on two parallel sides than on the other two will be, that the pyramid raised on the face ABCD (fig. 14.), instead of terminating in a single cube as in the example given above, will terminate in a range of cubes; or (supposing the cubes infinitely small) instead of terminating in a point, it will terminate in a ridge. The pyramid will therefore have for its two sides, contiguous to AB and DC, two trapeziums, and for its sides,

contiguous to AD and BC, two triangles. Let us suppose also, that with regard to the laminae of superposition which arise on the face BCGH (fig. 14.), the decrements follow the same law, and that each lamina decreases by two rows of cubes towards the lines BC and HG, and only by one row towards the lines CG, BH: The pyramid, in that case, will be placed in a direction opposite to the pyramid on ABCD, the ridge at the vertex of it running parallel to BC: the vertex of the pyramid raised upon CDFG must be parallel to CG: the pyramids on the three other sides of the cube ought to stand each like that which arises on the opposite face.

The sides of all the six pyramids thus formed amount to twelve trapeziums and twelve triangles. Every triangle is evidently contiguous and in the same plane with a trapezium of the nearest pyramid; consequently the secondary crystal thus formed consists of twelve sides, each of which is a pentagon.

Several other examples have been given by Mr Hauy; but these are sufficient to shew in what manner the various secondary forms of crystals are constructed, according to the theory of that ingenious philosopher.

In his researches on this subject, Mr Hauy perceived, that some crystals assumed secondary forms which could not be accounted for by any decrement whatever along the edges. Thus, for instance, some bodies, the primary form of which is cubic, are sometimes found crystallized in regular octagons. Mr Hauy explains the formation of these secondary crystals, by supposing that the decrement took place parallel, not to the edges, but to the diagonals of the faces of the primary cubes.

In order to comprehend this, let us suppose ABCD (fig. 20.) to be the surface of a lamina composed of small cubes, the bases of which are represented by little squares in the figure. It is evident, that the cubes $a, b, c, d, e, f, g, h, i$, are in the direction of the diagonal of the square ABCD; that the row of cubes g, v, k, u, x, y, z , is parallel to the diagonal; as also the row n, l, m, p, o, r, s ; and that the whole figure might be divided into rows of squares, each of which would be parallel either to the diagonal AC or DB.

Now we may conceive that the laminae of superposition, instead of decreasing by rows of cubes parallel to the edges AB, AD, decrease by rows parallel to the diagonals.

Let it be proposed to construct around the cube ABGF (fig. 21.), considered as a nucleus, a secondary solid, in which the laminae of superposition shall decrease on all sides by single rows of cubes, but in a direction parallel to the diagonals. Let ABCD (fig. 22.), the superior base of the nucleus, be divided into 81 squares, representing the faces of the small cubes of which it is composed. Figure 23. represents the superior surface of the first lamina of superposition; which must be placed above ABCD (fig. 22.) in such a manner that the points a', b', c', d' , (fig. 23.) answer to the points a, b, c, d , (fig. 22.). By this disposition the squares Aa, Bb, Cc, Dd (fig. 22.), which compose the four outermost rows of squares parallel to the diagonals AC, BD, remain uncovered. It is evident also, that the borders QV, ON, IL, GF (fig. 23.), project by one range beyond the borders AB, AD, CD, BC (fig. 22.), which is necessary, that the nucleus may be enveloped towards these edges: For if this were not the case,

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Crystallization. case, re-entering angles would be formed towards the parts AB, BC, CD, DA, of the crystal; which angles appear to be excluded by the laws which determine the formation of simple crystals, or, which comes to the same thing, no such angles are ever observed in any crystal. The solid must increase, then, in those parts to which the decrement does not extend. But as this decrement is alone sufficient to determine the form of the secondary crystal, we may set aside all the other variations which intervene only in a subsidiary manner, except when it is wished, as in the present case, to construct artificially a solid representation of a crystal, and to exhibit all the details which relate to its structure.

The superior face of the second lamina will be A'GL'K' (fig. 24.). It must be placed so that the points a'', b'', c'', d'', correspond to the points a' b' c' d' (fig. 23.), which will leave uncovered a second row of cubes at each angle parallel to the diagonals AC and BD. The solid still increases towards the sides. The large faces of the laminae of superposition, which in fig. 23. were octagons, in fig. 24. arrive at that of a square; and when they pass that term they decrease on all sides; so that the next lamina has for its superior face the square B'M'L'S' (fig. 25.), less by one range in every direction than the preceding lamina (fig. 24.). This square must be placed so that the points e', f', g', h', (fig. 25.) correspond to the points e, f, g, h (fig. 24.). Figures 26, 27, 28, and 29, represent the four laminae which ought to rise successively above the preceding; the manner of placing them being pointed out by corresponding letters, as was done with respect to the three first laminae. The last lamina z' (fig. 30.) is a single cube, which ought to be placed upon the square z (fig. 29.).

The laminae of superposition, thus applied upon the side ABCD (fig. 22.), evidently produce four faces, which correspond to the points A, B, C, D, and form a pyramid. These faces, having been formed by laminae, which began by increasing, and afterwards decreased, must be quadrilaterals of the figure represented in fig. 31.; in which the inferior angle C is the same point with the angle C of the nucleus (fig. 21. and 22.); and the diagonal LQ represents L'G' of the lamina A'G'L'K' (fig. 24.). And as the number of laminae composing the triangle LQC (fig. 31.) is much smaller than that of the laminae forming the triangle ZLQ, it is evident that the latter triangle will have a much greater height than the former.

The surface, then, of the secondary crystal thus produced, must evidently consist of 24 quadrilaterals (for pyramids are raised on the other 5 sides of the primary cube exactly in the same manner), disposed 3 and 3 around each solid angle of the nucleus. But in consequence of the decrement by one range, the three quadrilaterals which belong to each solid angle, as C (fig. 21.) will be in the same plane, and will form an equilateral triangle ZIN (fig. 32.). The 24 quadrilaterals, then, will produce 8 equilateral triangles; and consequently the secondary crystal will be a regular octagon. This is the structure of the octahedral sulphuret of lead and of muriat of soda.

Decrements which take place in this manner have been called by Mr Haüy *decrements on the angles*.

There are certain crystals in which the decrements on the angles do not take place in lines parallel to the diagonals, but parallel to lines situated between the dia-

gonals and the edges. This is the case when the subtractions are made by ranges of double, triple, &c. molecule. Fig. 33. exhibits an instance of the subtractions in question; and it is seen that the molecule which compose the range represented by that figure are assorted in such a manner as if of two there were formed only one; so that we need only to conceive the crystal composed of parallelopipedons having their bases equal to the small rectangles *abcd*, *edfg*, *hgil*, &c. to reduce this case under that of the common decrements on the angles. To this particular kind of decrement Mr Haüy has given the name of *intermediate*.

In other crystals the decrements, either on the edges or on the angles, vary according to laws, the proportion of which cannot be expressed but by the fraction $\frac{2}{3}$ or $\frac{3}{4}$. It may happen, for example, that each lamina exceeds the following by two ranges parallel to the edges, and that it may at the same time have an altitude triple that of a simple molecule. Figure 34. represents a vertical geometrical section of one of the kinds of pyramids which would result from this decrement; the effect of which may be readily conceived, by considering that AB is a horizontal line taken on the upper base of the nucleus, *baer* the section of the first lamina of superposition, *gfen* that of the second, &c. These decrements Mr Haüy has called *mixed*.

These two last species of decrements occur but rarely; Mr Haüy found them only in certain metallic substances.

All the metamorphoses to which crystals are subjected depend, according to Mr Haüy, on the laws of structure just explained, and others of the like kind. Sometimes the decrements take place at the same time on all the edges; as in the dodecahedron having rhombuses for its planes, as before mentioned; or on all the angles, as in the octahedron originating from a cube. Sometimes they take place only on certain edges or certain angles. Sometimes there is an uniformity between them; so that it is one single law by one, two, three ranges, &c. which acts on the different edges, or the different angles. Sometimes the law varies from one edge to the other, or from one angle to the other; and this happens above all when the nucleus has not a symmetrical form; for example, when it is a parallelopipedon, the faces of which differ by their respective inclinations, or by the measure of their angles. In certain cases the decrements on the edges concur with the decrements on the angles to produce the same crystalline form. It happens also sometimes that the same edge, or the same angle, is subjected to several laws of decrement that succeed each other. In short, there are cases where the secondary crystal has faces parallel to those of the primitive form, and which combine with the faces produced by the decrements to modify the figure of the crystal.

The crystals arising from a single law of decrement have been called by Mr Haüy *simple secondary forms*; those which arise from several simultaneous laws of decrement he has called *compound secondary forms*.

“If amidst this diversity of laws (he observes), sometimes insulated, sometimes united by combinations more or less complex, the number of the ranges subtracted were itself extremely variable; for example, were these decrements by twelve, twenty, thirty, or forty ranges, or more, as might absolutely be possible, the multitude

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of the forms which might exist in each kind of mineral would be immense, and exceed what could be imagined. But the power which effects the subtractions seems to have a very limited action. These subtractions, for the most part, take place by one or two ranges of molecules. I have found none which exceeded four ranges, except in a variety of calcareous spar, forming part of the collection of C. Gillet Laumont, the structure of which depends on a decrement by six ranges; so that if there exist laws which exceed the decrements by four ranges, there is reason to believe that they rarely take place in nature. Yet, notwithstanding these narrow limits by which the laws of crystallization are circumscribed, I have found, by confining myself to two of the simplest laws, that is to say, those which produce subtractions by one or two ranges, that calcareous spar is susceptible of two thousand and forty-four different forms: a number which exceeds more than fifty times that of the forms already known; and if we admit into the combination decrements by three and four ranges, calculation will give 8,388,604 possible forms in regard to the same substance. This number may be still very much augmented in consequence of decrements either mixed or intermediary.

“ The striæ remarked on the surface of a multitude of crystals afford a new proof in favour of theory, as they always have directions parallel to the projecting edges of the laminæ of superposition, which mutually go beyond each other, unless they arise from some particular want of regularity. Not that the inequalities resulting from the decrements must be always sensible, supposing the form of the crystals had always that degree of finishing of which it is susceptible; for, on account of the extreme minuteness of the molecules, the surface would appear of a beautiful polish, and the striæ would elude our senses. There are therefore secondary crystals where they are not at all observed, while they are very visible in other crystals of the same nature and form. In the latter case, the action of the causes which produce crystallization not having fully enjoyed all the conditions necessary for perfecting that so delicate operation of nature, there have been starts and interruptions in their progress, so that, the law of continuity not having been exactly observed, there have remained on the surface of the crystal vacancies apparent to our eyes. These small deviations are attended with this advantage, that they point out the direction according to which the striæ are arranged in lines on the perfect forms where they escape our organs, and thus contribute to unfold to us the real mechanism of the structure.

“ The small vacuities which the edges of the laminæ of superposition leave on the surface of even the most perfect secondary crystals, by their re-entering and salient angles, thus afford a satisfactory solution of the difficulty a little before mentioned; which is, that the fragments obtained by division, the external sides of which form part of the faces of the secondary crystal, are not like those drawn from the interior part. For this diversity, which is only apparent, arises from the sides in question being composed of a multitude of small planes, really inclined to one another, but which, on account of their smallness, present the appearance of one plane; so that if the division could reach its utmost bounds, all these fragments would be resolved into molecules similar to each other, and to those situated towards the centre.

“ The fecundity of the laws on which the variations of crystalline forms depend, is not confined to the producing of a multitude of very different forms with the same molecules. It often happens also, that molecules of different figures arrange themselves in such a manner as gives rise to like polyhedra in different kinds of minerals. Thus the dodecahedron with rhombuses for its planes, which we obtained by combining cubic molecules, exists in the granite with a structure composed of small tetrahedra, having isosceles triangular faces; and I have found it in sparry fluor (*fluat of lime*), where there is also an assemblage of tetrahedra, but regular; that is to say, the faces of which are equilateral triangles. Nay more, it is possible that similar molecules may produce the same crystalline form by different laws of decrement. In short, calculation has conducted me to another result, which appeared to me still more remarkable, which is, that, in consequence of a simple law of decrement, there may exist a crystal which externally has a perfect resemblance to the nucleus, that is to say, to a solid that does not arise from any law of decrement *.”

* Ann. de
Chim. xvii.
225.

SUCH is a short view of the theory by which Mr Haüy explains the various crystalline forms of the same substance. We would with pleasure have entered more into detail, had not most of his examples been deduced from substances which belong rather to mineralogy than to the elements of chemistry. This theory, to say no more of it, is, in point of ingenuity, inferior to few; and the mathematical skill and industry of its author are intitled to the greatest applause.

But what we consider as the most important part of that philosopher's labours, is the method which they point out of discovering the figure of the integrant particles of crystals; because it may pave the way for calculating the affinities of bodies, which is certainly by far the most important part of chemistry. This part of the subject, therefore, deserves to be investigated with the greatest care.

Mr Haüy has found, that the primitive form of all the crystals which he has examined may be reduced to six; 1. The parallelepipedon in general, comprehending the cube, the rhomboid, and all solids terminated by six sides parallel two and two; 2. The regular tetrahedron; 3. The octahedron with triangular sides; 4. The hexagonal prism; 5. The dodecahedron bounded by rhombs; 6. The dodecahedron bounded by isosceles triangles. Were we to suppose that these primitive forms are exactly similar to the form of the integrant particles which compose them, it would follow, that the integrant particles of all the crystals hitherto formed have only six different forms. This supposition, however, is not probable; because the same nucleus has been discovered in different species of minerals, and because we can easily conceive integrant particles of different forms, combining in such a manner as to compose nuclei of the same figure, just as we have seen that different primitive forms are capable of producing the same secondary form. Still, therefore, in endeavouring to discover the integrant particles of bodies, there are difficulties to remove, which hitherto, at least, have been unsurmountable. But the theory of Mr Haüy may be considered as a first step towards the discovery; and a step in researches of so difficult a nature is of very great consequence.

Conclusion.

Conclusion.

WE have now finished the three first parts of this article, which comprehend all the elementary part of chemistry. We ought now to proceed to the fourth part, which was to consist of a chemical examination of substances as they exist in nature in the mineral, vegetable, and animal kingdoms; but this, for various reasons, we shall defer till we come to the words MINERALOGY, and *Animal and Vegetable SUBSTANCES*.

We shall finish this article with a few remarks upon the chemical nomenclature, which for some time past has been an object of serious attention.

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mical no-
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Chemistry was unfortunately first cultivated by a set of ignorant men, filled with the highest notions of their own importance, and buoyed up with the mighty feats which they were to perform by their art. The little which they did know they were anxious to conceal; and their anxiety was no less to inspire the world with high ideas of their knowledge and power. The consequence of this was, that they loaded chemistry with the most ridiculous and whimsical names that can well be conceived. *Liver of sulphur, mercury of life, horned moon, butter of antimony, the double secret, the coralline secret, the secret of vitriol, the wonderful salt, the secret salt, the salt with many virtues, the salt of two ingredients, the foliated earth of tartar*, were the names by which they distinguished some of the most familiar preparations; and, were it worth while, a great many more names of the same stamp might easily be added.

As soon as chemistry had attracted the attention of men of science, the absurdity of its nomenclature was felt, and several partial improvements were at different times made in it. Macquer, in particular, discarded many of the ancient names, and substituted others less exceptionable in their place.

But soon after the publication of the first edition of his Dictionary, an evil began to be felt severely, which never could have occurred to the earlier chemists. Hitherto the number of objects which had engaged the attention of those who cultivated the science had been very limited; the acids amounted only to five, the earths to four, the metals to 12 or 14, and the neutral salts scarcely exceeded 20 or 30. To remember names for so small a number of bodies, however ridiculous they happened to be, was no very difficult matter. But about that time, in consequence chiefly of the discovery of fixed air by Dr Black, which laid the foundation of pneumatic chemistry, the science began to extend itself, and to enlarge its boundaries with inconceivable rapidity. The number of bodies connected with it, and which it had to describe, soon became immense; and if every one of them received names not dependant upon one another, the most retentive memory could not have remembered the thousandth part of them.

The difficulty of studying chemistry from that time till the year 1782 must have been very great: it was even perceived and complained of by the masters of the science. In 1782 Mr de Morveau, who had undertaken the chemical part of the *Encyclopedie Methodique*, published in the *Journal de Physique* a new chemical nomenclature, and at the same time invited all those persons who were fond of chemistry, and interested in its progress, to propose objections and improvements.

This new nomenclature was formed agreeable to the five following rules:

1. Every substance ought to have a name, and not to be denoted by a phrase.

2. Names ought to be as much as possible conformable to the nature of the things signified by them.

3. When the character of a substance is not well enough known to determine the denomination, a name which has no meaning is preferable to one which conveys a false idea.

4. In the choice of new words those ought to be preferred which have their roots in the dead languages most generally known, that the word may be easily suggested by the sense, and the sense by the word.

5. The new words ought to be as suitable as possible to the genius of the languages for which they are formed.

This nomenclature was approved of by Macquer, and by Bergman, who had himself proposed one upon a plan not very different (D). He wrote to Morveau, and exhorted him to prosecute his undertaking with courage.

“Do not spare (says he) a single improper denomination; those that are already learned will be always so, and those that are not will learn the sooner*.”

This nomenclature was adopted by several chemists, and it was used in the greatest part of the first volume face.

of the chemical part of the *Encyclopedie Methodique*; but the new discoveries in chemistry had produced a more accurate method of reasoning, and had enabled Lavoisier to explain the phenomena of the science without the assistance of the hypothetical principle of phlogiston, which had hitherto been necessary. As the language, even in its improved state, was accommodated to this principle, and presupposed its existence, new changes became evidently necessary, in order that, according to Morveau's rule, the words might denote the most essential properties of the things intended to be signified. Accordingly, when Morveau was in Paris in 1787, Lavoisier, Berthollet, and Fourcroy, agreed to labour in concert with him to bring the chemical nomenclature still nearer to perfection. These philosophers, assisted by the mathematicians of the Royal Academy and by several chemists, formed a new nomenclature, which they made public in 1787.

For some time little attention was paid to this nomenclature by foreign chemists, and it seemed generally to be disapproved. The adherents of the phlogistic system in France, who were exceedingly numerous, viewed it as an engine artfully formed to undermine and destroy their favourite theory. They resolved, therefore, unanimously, to crush, if possible, this new instrument, which they considered as

— in nostros fabricata machina muros;
Inspectura domos, venturaque desuper urbi.

And for this purpose they exerted themselves with a vigour, which was only equalled by the zeal and indefatigable exertions of their antagonists. A kind of civil war was thus kindled in the republic of letters, which was carried on with great animosity: And posterity will see, with regret, men of undoubted genius at times divesting themselves of the armour of truth and of candour, and endeavouring to serve their party, and stab their adversaries with darts steeped in the poison of calumny and falsehood*. This contest, however, which was not confined to France, was productive of good effects, which infinitely surpassed all the bad ones.

* See the
Journ. de
Phys. for
1788, 89,
occasionally,
90, 91, &c.
1788.

(D) See his thoughts on a natural history of fossils in the 4th vol. of his *Opusc.*

Conclusion.

occasioned an accumulation of facts, produced a rigid examination of theories and opinions, introduced an accuracy into chemical experiments which has been of the most essential service, and gave that tone and vigour to the cultivators of chemistry which have brought to light the most sublime and unlooked-for truths. It deserves attention, and the fact is no inconsiderable evidence in favour of the antiphlogistic theory, that almost all the illustrious chemists who at present adhere to it declared originally against it. Berthollet, Morveau, Black, Kirwan, and many other chemists who are now its ablest defenders, were at first its most powerful opponents. "This system had hardly been published in France (says Dr Priestley, who still continues to adhere to the doctrine of phlogiston) before the principal philosophers and chemists of England, notwithstanding the rivalry which has long subsisted between the two countries, eagerly adopted it. Dr Black in Edinburgh, and as far as I hear all the Scots, have declared themselves converts, and, what is more, the same has been done by Mr Kirwan, who wrote a pretty large treatise in opposition to it. The English reviewers of books, I perceive, universally favour the new doctrine. In America, also, I hear of nothing else. It is taught, I believe, in all the schools on this continent, and the old system is entirely exploded. And now that Dr Crawford is dead, I hardly know of any person except my friends of the Lunar Society at Birmingham, who adhere to the doctrine of phlogiston; and what may now be the case with *them* in this age of revolutions, philosophical as well as civil, I will not at this distance answer for.

"It is no doubt *time*, and of course opportunity of examination and discussion, that gives stability to any principles. But this new theory has not only kept its ground, but has been constantly and uniformly advancing in reputation more than *ten years*, which, as the attention of so many persons, the best judges of every thing relating to the subject, has been unremittingly given to it, is no inconsiderable period. Every year of the last twenty or thirty has been of more importance to science, and especially to chemistry, than any ten in the preceding century*."

* Considerations on the doctrine of phlogiston, Introduction.

We have endeavoured in the preceding article to state the different theories which have successively made their appearance in *chemistry* with as much fairness as possible. If we have succeeded, the reader will be enabled to judge for himself which of these theories is the most consistent with truth; or rather, if we have succeeded, he will join with us in thinking that the theory of Lavoisier is in most points an accurate account of what takes place in nature.

This we consider as a sufficient reason for having adopted the new nomenclature; for, as Morveau long ago observed, most of the objections that were made to it were rather levelled at the doctrine of those who formed it, than at the nomenclature itself. Its superiority to every other nomenclature cannot be disputed for an instant; and the vast facility which it has

added to the acquisition of chemistry, must be acknowledged by every one who knows any thing about the science. The Table of the new nomenclature will not be expected here, as it has been already given in the Appendix to the article CHEMISTRY in the *Encyclopaedia*. At any rate, it would have been unnecessary, as we have used the new names all along; and therefore our readers must by this time be well acquainted with them.

Upon the almost infinite number of criticisms which have been made on the new nomenclature, and the many new terms which since its publication have been successively proposed, we do not mean to enter. Few of these terms can bear a comparison with the French nomenclature, and still fewer have any claim to be preferred to it; and the philosophers who persist in these useless innovations, are more probably actuated by the desire of appearing to have a share in the great revolution which chemistry has undergone, than by any hopes of being able to improve the accuracy or the elegance of its language. How few have displayed the magnanimity of an illustrious philosopher of our own country, who, though he had invented a new nomenclature himself, exhorted his pupils not to use it, but to adopt that of the French chemists, which was likely soon to come into universal use.

Even the etymological remarks which have been made on the new nomenclature, we consider as either of little consequence or as ill-founded. The philosophers who formed it have displayed a sagacity and a moderation which could not be excelled, and have, upon the whole, formed a language much more systematic, and much more perfect, than could have been expected; and whoever compares it with the nomenclature proposed in 1782 by Morveau, will see how great a share of it is due to that illustrious philosopher.

Notwithstanding what we have here said, we would not be understood to consider the new nomenclature as already arrived at a state of such absolute perfection, that no alteration whatever can be made in it except for the worse. Such perfection belongs not to the works of man; nor if it did, could it be expected in this case, if we consider for a moment the present state of chemistry. New discoveries must occasion additions and alterations in the nomenclature; but the authors of the new nomenclature have given us the rules by which changes and additions are to be made; and if they are adhered to, we may expect with confidence that the language of chemistry will in its advancement to perfection keep pace with the science. We have in the preceding article ventured in an instance or two to adopt little improvements that have been suggested by later writers. We have taken the liberty, too, of choosing, from the variety which the British chemists have proposed, that mode of spelling each of the terms which appeared to us most agreeable to the English idiom, and most conformable to analogy: Whether or not we have made a proper choice must be left for others to determine.

Conclusion.

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C H E

Cherubim. CHERUBIM were emblematical figures; of which an account, a very vague one indeed, has been given in the *Encyclopædia Britannica*. We are far from thinking ourselves qualified to improve that account, or to explain emblems in the Jewish worship, which even Josephus did not understand; and we certainly should not have resumed the subject but to gratify a numerous class of our readers, and to comply with the request of some highly respected friends.

The followers of Mr Hutchinson, who are firmly persuaded that their master brought to light from the writings of the Old Testament many important doctrines which had lain concealed from all the piety, all the industry, and all the learning of 1700 years, believe that, among other things, he and they have been able to ascertain the form and the import of the Hebrew Cherubim. Their discoveries on this subject, as we have been told by better judges than we pretend to be, are more clearly stated by Mr Parkhurst in his Hebrew Lexicon, than by any other writer of that school. We shall therefore lay before our readers his doctrine respecting the form of the artificial cherubs, as well as of their emblematical meaning; and subjoin a few remarks, which the nature of his reasoning has forced from us.

“*First*, then, as to the form of the artificial cherubs in the tabernacle and temple, Moses (says our author) was commanded (Exod. xxv. 18, 19.) ‘Thou shalt make two cherubs: of beaten gold shalt thou make them at the two ends of the mercy-seat. And thou

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shalt make one cherub at the one end, and the other cherub at the other end: מן חבפחה, out of the mercy-seat (Margin Eng. Translat. of the matter of the mercy-seat) shall ye make the cherubs at the two ends thereof.’ All which was accordingly performed (Exod. xxxvii, 7, 8.), and these cherubs were with the ark placed in the holy of holies of the tabernacle (Exod. xxvi. 33, 34. xl. 20.); as those made by Solomon were afterwards in the holy of holies of the temple (1 Kings vii. 23, 27.)

We may observe that in Exodus Jehovah speaks to Moses of the cherubs as of figures well known; and no wonder since they had always been among believers in the holy tabernacle from the beginning. (See Gen. iii. 24. Wisd. ix. 8. And though mention is made of their faces (Exod. xxv. 20. 2 Chron. iii. 13.), and of their wings, (Exod. xxv. 20. 1 Kings viii. 7. 2 Chron. iii. 11, 12.); yet neither in Exodus, Kings, nor Chronicles, have we any particular description of their form. This is however very exactly, and, as it were, anxiously supplied by the prophet Ezekiel, ch. i. 5. ‘Out of the midst thereof (*i. e.* of the fire infolding itself, ver. 4.) the likeness of four living creatures or animals; דמות למה the likeness of a man (being) with them.’ This last Hebrew expression cannot mean that they, *i. e.* the four animals, had the likeness of a man, which interpretation would indeed make the prophet contradict himself (comp. ver. 10.); but it imports that the likeness of a man in glory, called (verse 26.) דמות במראה אדם the likeness as the appearance of a man,

Cherubim. and particularly described in that and the following verses, was with them. Ver. 6. 'And there were four faces to one (דמות or similitude), and four wings to one, ליהם to them. So there were at least two compound figures. Ver. 10. 'And the likenesses of their faces; the face of a man, and the face of a lion, on the right side, to them four; and the face of an ox to them four; and the face of an eagle to them four.' Ezekiel knew (ch. x. 1.—20.) that these were cherubs. Ver. 21. 'Four faces לאחד to one (cherub) and four wings to one.' This text also proves that the prophet saw more cherubs than one, and that each had four faces and four wings. And we may be certain that the cherubs placed in the holy of holies were of the form here described by the priest and prophet of Ezekiel, because we have already seen from Exodus, 1 Kings, and 2 Chronicles, that they likewise had faces and wings, and because Ezekiel knew what he saw to be cherubs, and because there were no four-faced cherubs any where else but in the holy of holies; for it is plain from a comparison of Exod. xxvi. 1, 31. 1 Kings vi. 29, 32. and 2 Chron. iii. 14. with Ezekiel xli. 18, 19, 20. that the artificial cherubs on the curtains and veil of the tabernacle, and on the walls, doors, and veil of the temple, had only two faces; namely, those of a lion and of a man.

"For it must be observed further, that, as the word כרוּב is used for one compound figure with four faces, and כרוּבִים in the plural for several such compounds (see Exod. xxv. 18, 19. xxxvii. 8. 1 Kings vi. 23—26.), so is כרוּב applied to one of the cherubic animals, as to the ox, Ezek. x. 14.; (compare ch. i. 10.) to the coupled cherub, or lion-man, Ezek. xli. 18.; and כרוּבִים to several of the cherubic animals, as to several oxen, 1 Kings vii. 36. (compare ver. 29.) to several coupled cherubs, Exod. xxvi. 1. 1 Kings vi. 32, 35. & al. I proceed to shew.

"Secondly, of what the cherubs were emblems, and with what propriety.

"That the cherubic figures were emblems or representatives of something beyond themselves is, I think, agreed by all, both Jews and Christians. But the question is, Of what they were emblematical? To which I answer in a word, Those in the holy of holies were emblematical of the ever-blessed Trinity in covenant to redeem man, by uniting the human nature to the Second Person; which union was signified by the union of the faces of the lion and of the man in the cherubic exhibition, Ezek. i. 10. compare Ezek. xli. 18, 19. The cherubs in the holy of holies were certainly intended to represent some beings in heaven, because St Paul has expressly and infallibly determined that the holy of holies was a figure or type of heaven, even of that heaven where is the peculiar residence of God (Heb. ix. 24.). And therefore these cherubs represented either the ever-blessed Trinity with the man taken into the essence, or created spiritual angels. The following reasons will, I hope, clearly prove them to be emblematical of the former, not of the latter:

"1st, Not of angels; because (not now to insist on other circumstances in the cherubic form) no tolerable reason can be assigned why angels should be exhibited with four faces apiece.

"2^{dly}, Because the cherubs in the holy of holies of the tabernacle were, by Jehovah's order, 'made out of the matter of the mercy-seat, or beaten out of the same

piece of gold as that was' (Exod. xxv. 18, 19. xxxvii. 9.). Now the mercy-seat, made of gold and crowned, was an emblem of the Divinity of Christ (See Rom. iii. 25. The cherubs therefore represented not the angelic, but the Divine nature.

"3^{dly}, The typical blood of Christ was sprinkled before them on the great day of atonement (compare Exod. xxxvii. 9. Lev. xvi. 14. Heb. ix. 7, 12.): And this cannot in any sense be referred to created angels, but must be referred to Jehovah only; because,

"4^{thly}, The high priest's entering into the holy of holies on that day, represented Christ's entering with his own blood into heaven 'to appear in the presence of God for us' (Heb. ix. 7, 24.) And,

"5^{thly}, When God 'raised Christ (the humanity) from the dead, he set him at his own right hand in the heavenly places, far above, ΤΡΕΠΑΝΩ, all principality and power, and might and dominion, and every name that is named, not only in this world, but also in that which is to come (Eph. i. 21.). Angels and authorities and powers being made subject unto him' (1 Peter iii. 22.)

"6^{thly}, The prophet Ezekiel saith (ch. x. 20.), 'This is the living creature, חיה (which must mean one compound figure, comp. ver. 14.) that I saw' חיה instead of, a substitute of 'the Aleim of Israel. חיה it is granted, may refer either to situation or substitution, (see Gen. xxx. 2. l. 19.) as the sense requires. Here, notwithstanding what is said ver. 19. the latter sense is preferable; because it was the glory of the God of Israel, i. e. the God-man in glory, (compare ch. i. 26.) not the Aleim (the Trinity) of Israel that were over the cherubim; and the text says not, *these* were the living creatures, but, *this* was the living creature, which I saw יהוה אלהי ישראל. Now the glory was over both the cherubims, ver. 19. but one compound cherub only was a substitute of the Aleim.

"If it should be here asked, Why then were there two compound cherubs in the holy of holies? I answer, Had there not in this place been two compound cherubs, it would have been naturally impossible for them to represent what was there designed; for otherwise, all the faces could not have looked inwards toward each other, and down upon the mercy-seat, and on the interceding high priest sprinkling the typical blood of Christ, (see Exod. xxxvii. 9.) and at the same time have looked outward toward the temple, לבית (Vulg. ad domum exteriorum, to the outer-house,) 2 Chron. iii. 13. Or, in other words, the Divine Persons could not have been represented as witnessing to each other's voluntary engagements for man's redemption, as beholding the sacrifice of Christ's death, typified in the Jewish church, and at the same time as extending their gracious regards to the whole world. (See Isa. liv. 5. and Spearman's Inquiry, p. 382. edit. Edinburgh.)

"The coupled cherub, or lion-man, on the veil and curtains of the outer tabernacle, and on the veil, doors, and walls of the temple, accompanied with the emblematic palm-tree, is such a striking emblem of the lion of the tribe of Judah (Rev. v. 5.) united to the man Christ Jesus, as is easy to be perceived, but hard to be evaded. These coupled cherubs appropriate the tabernacle or temple, and their veils, as emblems of Christ, and express in visible symbols what he and his apostles do in words. See John ii. 19, 21. Heb. viii. 2. ix. 11.

Cherubim. x. 20. comp. Matt. xxvii. 51. And as the texts just cited from the New Testament afford us divine authority for asserting that the outer tabernacle or temple was a type of the body of Christ, so they furnish us with an irrefragable argument to prove that the cherubs on their curtains or walls could not represent angels. For did angels dwell in Christ's body? No, surely: But 'in him dwelt all the fulness of the Godhead bodily.' (Col. ii. 9.)

"I go on to consider the propriety of the animals in the cherubic exhibition representing the Three Persons in the ever-blessed Trinity. And here to obviate any undue prejudice which may have been conceived against the Divine Persons being symbolically represented under any animal forms whatever, let it be remarked that Jehovah appeared as three men to Abraham (Gen. xviii.); that the serpent of brass set up by God's command in the wilderness was a type or emblem of Christ, God-man, lifted up on the cross (comp. Num. xxxi. 1—9. with John iii. 14, 15.); that at Jesus's baptism the Holy Spirit descended in a bodily shape, like a dove, upon him (Luke iii. 21, 22.); that Christ, as above intimated, is expressly called the lion of the tribe of Judah (Rev. v. 5.); and continually in that symbolical book set before us under the similitude of a lamb. All these are plain scriptural representations, each of them admirably suited, as the attentive reader will easily observe, to the particular circumstances or specific design of the exhibition. Why then should it appear a thing incredible, yea why not highly probable, that Jehovah Aleim should, under the typical state, order his own Persons and the union of the manhood with the essence to be represented by animal forms in the cherubim of glory? Especially if it be considered that the three animal forms, exclusive of the man (who stood for the very human nature itself) are the chief of their respective genera: the ox or bull of the tame or graminivorous; the lion, of the wild or carnivorous; and the eagle, of the winged kind.—But this is by no means all: For as the great agents in nature, which carry on all its operations, certainly are the fluid of the heavens, or, in other words, the fire at the orb of the sun, the light issuing from it, and the spirit or gross air constantly supporting, and concurring to the actions and effects of the other two; so we are told (Psal. xix. 1.) that השמים אל the heavens (are) the means of declaring, recounting, or particularly exhibiting the glory of God, even his eternal power and godhead, as St Paul speaks, Rom. i. 20. And accordingly Jehovah himself is sometimes, though rarely (I presume for fear of mistakes) called by the very name שמים or שמיא heavens in the Old Testament, see 2 Chron. xxxii. 20. (comp. 2 Kings xix. 14. Isa. xxxvii. 15.) Dan. iv. 23. or 26.; as he is more frequently expressed by ουρανος heaven in the New. (See Mat. xxi. 25. Mark xi. 30. 31. Luke xv. 18, 21. xx. 4, 5. John iii. 27.) Yea not only so, but we find in the Scriptures both of the Old and New Testament, that the Persons of the eternal Three and their economical operations in the spiritual, are represented by the three conditions of the celestial fluid and their operations in the material world. Thus the peculiar emblem of the Word or Second Person is the נור or light, and he is and does that to the souls or spirits of men which the material or natural light is and does to their bodies. (See inter al. 2 Sam. xxiii. 4. Isa. xlix. 6. Ix. 1.

Mal. iv. 2. or iii. 20. Luk i. 78. ii. 32. John i. 4—9. viii. 12. xii. 35, 36, 46.) The Third Person has no other distinctive name in scripture but \aleph in Hebrew, and $\piνευμα$ in Greek (both which words in their primary sense denote the material spirit or air in motion), to which appellation the epithet $\קדש$, $\alphaγιος$ holy, or one of the names of God, is usually added: and the actions of the Holy Spirit in the spiritual system are described by those of the air in the natural (See John iii. 8. xx. 22. Acts ii. 2.) Thus, then, the second and Third Persons of the ever-blessed Trinity are plainly represented in scripture by the material light and air. But it is further written, Jehovah thy Aleim is a consuming fire. Deut. iv. 24. (Comp. Deut. ix. 23. Heb. xii. 29. Psal. xxi. 10. lxxviii. 21. Nah. i. 2.) And by fire, derived either immediately or mediately from heaven, were the typical sacrifices consumed under the old dispensation. Since, then, Jehovah is in scripture represented by the material heavens, and even called by their name, and especially by that of fire, and since the Second and Third Persons are exhibited respectively by the two conditions of light and spirit, and since fire is really a condition of the heavenly fluid as much distinct from the other two as they are from each other, it remains that the peculiar emblem of the First Person (as we usually speak) of the eternal Trinity, considered with respect to the other two, be the fire.

"Bearing then in mind that the personality in Jehovah is in scripture represented by the material Trinity of nature; which also, like their divine antitype, are of one substance, that the primary scriptural type of the Father is fire; of the Word, light; and of the Holy Ghost, spirit, or air in motion; we shall easily perceive the propriety of the cherubic emblems. For the ox or bull, on account of his horns, the curling hair on his forehead, and his unrelenting fury when provoked (see Psal. xxii. 13.) is a very proper animal emblem of fire; as the lion from his usual tawny gold-like colour, his flowing mane, his shining eyes, his great vigilancy and prodigious strength, is of light; and thus likewise the eagle is of the spirit or air in action, from his being chief among fowls, from his impetuous motion (see 2 Sam. i. 23. Job ix. 26. Jer. iv. 13. Lam. iv. 19.), and from his towering and surprising flights in the air (see Job xxxix. 27. Prov. xxiii. 5. xxx. 19. Isa. xl. 31. and Bochart, vol. iii. p. 173.) And the heathen used these emblematic animals, or the like, sometimes separate, sometimes joined, in various manners, as representatives of the material Trinity of nature, which they adored. These particulars Mr Hutchinon has proved with a variety of useful learning, vol. vii. p. 381, et seq. and any person who is tolerably acquainted with the heathen mythology will be able to increase his valuable collection with many instances of the same kind from modern as well as ancient accounts of the pagan religions.

"Thus, then, the faces of the ox, the lion, and the eagle, representing at second hand the Three Persons of Jehovah, the Father, the Word, and the Holy Spirit; and the union of the divine light with man being plainly pointed out by the union of the faces of the lion and the man (see Ezek. i. 10. xli. 18.), we may safely assert, that the cherubim of glory (Heb. ix. 5.) in the holy of holies were divinely instituted and proper emblems of the Three Eternal Persons in covenant to redeem

Cherubim. redeem man, and of the union of the divine and human natures in the person of Christ. And we find (Gen. iii. 24) that immediately on Adam's expulsion from paradise, and the cessation of the first or paradisaical dispensation of religion, Jehovah Aleim himself set up these emblems, together with the burning flame *ההרהב* rolling upon itself, to keep the way to the tree of life; undoubtedly, considering the services performed before them, not to hinder, but to enable, man to pass through it."

Thus far Mr Parkhurst; and to his dissertation where is the man who will deny the merit of erudition, combined with ingenuity? To the latter part of his reasoning, however, objections obtrude themselves upon us of such force, that we know not how to answer them. The reader observes, that, according to this account, the cherubim are only at *second hand* emblematical of the Holy Trinity, and that the *primary* emblem is that fluid which the author conceives to fill the solar system, and to be one substance under the different appearances or modifications of *fire, light, and gross air*. But unfortunately for this reasoning, we are as certain as we can be of any matter of fact, that *fire* and *air* are *not* one substance; that the *gross air* itself is compounded of very *different* substances; and that even *light* is a different substance from that which causes in us the sensation of heat, and to which modern chemists have given the name of *caloric* (See *CHEMISTRY-Index* in this Supplement). We admit, that the *primary atoms* of all matter *may be* substances of the very same kind, though we do not *certainly know* that they are: but this makes nothing for our author's hypothesis; because the sun and all the planets must, in that case, be added to his one substance, which would no longer appear under a triple form. Could it indeed be proved, that all men from Adam downwards, who made use of cherubic figures for the very same purpose with the ancient Jews, *believed* that fire, air, and light, are different modifications of the same substance, their belief, though erroneous, would be a sufficient foundation for our author's reasoning; but of this no proof is attempted, and certainly none that is satisfactory could be brought.

Our learned author, indeed, takes much for granted without proof. He has not proved that anywhere the bull was the emblem or hieroglyphic of *fire*, the lion of *light*, or the eagle of *air*. We do not, it must be owned, know that such hieroglyphics were *not* used in Egypt and other countries before the introduction of alphabetical characters; but unless they were so used by Adam, all that is here said of the *propriety* of these emblems must go for nothing: Indeed we see not their peculiar propriety. The tawny colour, flowing mane, and fierceness of the lion, might, for any thing that we can perceive to the contrary, represent *fire* as fitly as the horns, curling hair, and fury of the bull; and if it be true, as is generally said, that the eagle can look steadily on the sun, he seems, of all the three, to be the fittest emblem of light.

But there are other objections to this interpretation of the word cherubim. The four animals in the Revelation, which were undoubtedly cherubim, as well as the four and twenty elders, fell down before the Lamb, and worshipped God*. Now, says Dr Gregory, Sharp, "it is scarce to be conceived, if these four beasts were representatives of the divine persons, that they could with

any propriety, or without the greatest solecism, be said and described to fall down before and worship other emblematical representations of the same divine nature and perfections: And therefore, whatever these beasts were emblems of, they could not be cherubim in Mr Hutchinson's sense of that word; it being as contrary to the rational explanation of a vision to say that one emblem of the divinity should worship another emblem of it, as it is contrary to the reason of mankind, and to all our notions either of the Godhead or of worship, to say that the Trinity worshipped the Trinity, or any one Person in the Trinity."

This objection is admitted by our learned author to be a very plausible one. To us it appears unanswerable. He answers it, however, in the following words:

"Let it be carefully observed, that these representations in Rev. ch. v. and xix. are not only visionary but hieroglyphical, and therefore must be explained according to the analogy of such emblematical exhibitions; and as at ver. 6. 'the lamb, as it had been slain, having seven horns and seven eyes, standing in the midst of the throne, and of the four animals, and of the four-and-twenty elders,' is evidently symbolical of the Lamb of God now raised from the dead, and invested with all knowledge and power both in heaven and in earth; so 'the four animals falling down before him' (ver. 8.), and, as it is expressed (ch. xix. 4.), 'worshipping God who sat upon the throne,' must, in all reason, be explained symbolically likewise, not from any abstract or metaphysical notions we may have framed to ourselves of worship in general, but from the specific and peculiar circumstances of the case before us. Thus, likewise, when in 1 Chron. xxix. 20. 'All the congregation worshipped Jehovah and the king, namely David, the worship to both is expressed by the same strong phrase—*וירדו* prostrated themselves to, *LXX.* *προσεκύνουσιν*; yet surely no one will say that the people meant to worship David as God, but only to acknowledge him as king. So Adonijah, who had contested the crown with Solomon, came, *וירדו* and worshipped King Solomon (1 Kings i. 53.), not as God doubtless, but as king, thereby surrendering his own claim to the throne. However 'contrary therefore it may be to the reason of mankind, and to all our notions either of the Godhead or of worship, to say that the Trinity worshipped the Trinity, or any one Person of the Trinity,' *i. e.* with divine worship as a creature worships his Creator; yet it is by no means contrary to the rational and scriptural explanation of an emblematic vision, to say that the hieroglyphical emblems of the whole ever-blessed Trinity fell down and worshipped the hieroglyphical emblem of the God-man, or God who sat upon the throne. Since such falling down, prostration, or worshipping, was the usual symbolical act, as it still is in the east, not only of divine worship, but of acknowledging the regal power to be in the person so worshipped; and these acts of the cherubic animals in Rev. v. 6. xix. 4. meant nothing more than either a cession of the administration of all divine power to Christ God-man, or a declaration of the divine Persons, by their hieroglyphical representatives, that He must reign till all his enemies were made his footstool. Comp. Mat. xxviii. 18. 1 Cor. xv. 25."

With every inclination to honour the memory of Mr Parkhurst, who was certainly a scholar, and, which is

* Ch. v. 8.
xix. 4.

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of more value, a pious and a good man, we cannot help considering this answer as mere trifling. In the 18th Psalm, the Lord is said to "ride upon a cherub;" and in Ezekiel, chap. i. there is said to have "been over the heads of the cherubim *a throne*, and upon that throne the likeness or appearance of a man," whom we take to be the Son of God incarnate. But is there any country in which the regal power of the sovereign is acknowledged by his riding, not upon his subjects, but upon other co-equal sovereigns? or, in which it is the custom for the sovereign to place his viceroy (for such our Saviour in his *human nature* certainly is) in his throne above himself?

We must therefore confess, that we know not of what the cherubic figures were emblematical, and that he who labours to establish the doctrine of the ever blessed Trinity by such criticisms and reasonings as those which we have examined, is either a secret enemy to that doctrine, or a very injudicious friend.

CHESSE, the celebrated game, of which a copious account has been given in the Encyclopædia, is affirmed by Sir William Jones to have been invented by the Hindoos. "If evidence were required to prove this fact (says he *), we may be satisfied with the testimony of the Persians, who, though as much inclined as

other nations to appropriate the ingenious inventions of a foreign people, unanimously agree that the game was imported from the west of India in the sixth century of our era. It seems to have been immemorially known in Hindostan by the name of *Chaturanga*, i. e. the four *angâs*, or members of an army; which are these, *elephants*, *horses*, *chariots*, and *foot soldiers*; and in this sense the word is frequently used by epic poets in their descriptions of real armies. By a natural corruption of the pure Sanscrit word, it was changed by the old Persians into *Chetrang*; but the Arabs, who soon after took possession of their country, had neither the initial nor final letter of that word in their alphabet, and consequently altered it further into *Shetranj*, which found its way presently into the modern *Persian*, and at length into the dialects of India, where the true derivation of the name is known only to the learned. Thus has a very significant word in the sacred language of the Brahmins been transformed by successive changes into *axedrez*, *scacchi*, *échecs*, *chefs*, and, by a whimsical concurrence of circumstances, has given birth to the English word *check*, and even a name to the *exchequer* of Great Britain."

It is confidently asserted that Sanscrit books on *chess* exist in Bengal; but Sir William had seen none of them when he wrote the memoir which we have quoted. He exhibits, however, a description of a very ancient Indian game of the same kind, but more complex, and in his opinion more modern, than the simple chess of the *Persians*. This game is also called *Chaturanga*, but more frequently *Chaturaji*, or the *four kings*, since it is played by four persons representing as many princes, two allied armies combating on each side. The description is taken from a book called *Bhauishya Purân*; in which the form and principal rules of this factitious warfare are thus laid down: "Eight squares being marked on all sides, the *red army* is to be placed to the east, the *green* to the south, the *yellow* to the west, and the *black* to the north. Let the *elephant* (says the author of the *Purân*) stand on the left of the *king*; next to him the

horse; then the *boat*; and before them all, four *foot-soldiers*; but the *boat* must be placed in the angle of the board."

"From this passage (says the president) it clearly appears, that an army with its four *angâs* must be placed on each side of the board, since an *elephant* could not stand, in any other position, on the left hand of each *king*; and RADHACANT (a Pandit) informed me, that the board consisted, like our's, of 64 squares, half of them occupied by the forces, and half vacant. He added, that this game is mentioned in the oldest law-books, and that it was invented by the wife of a king, to amuse him with an image of war, while his metropolis was besieged, in the second age of the world. A *ship* or *boat* is absurdly substituted, we see, in this complex game for the *rat*, or armed *chariot*, which the *Bengalese* pronounce *rot*, and which the Persians changed into *rokk*; whence came the *rook* of some European nations; as the *vierge* and *sal* of the French are supposed to be corruptions of *ferz* and *fil*, the *prime minister* and *elephant* of the Persians and Arabs."

As fortune is supposed to have a great share in deciding the fate of a battle, the use of dice is introduced into this game to regulate its moves; for (says the *Purân*) "if *cinque* be thrown, the *king* or a *pawn* must be moved; if *quatre*, the *elephant*; if *trois*, the *horse*; and if *deux*, the *boat*. The *king* passes freely on all sides, but over one square only; and with the same limitation the *pawn* moves, but he advances straight forward, and kills his enemy through an angle. The *elephant* marches in all directions as far as his driver pleases; the *horse* runs obliquely, traversing the squares; and the *ship* goes over two squares diagonally." The *elephant*, we find, has the powers of our *queen*, as we are pleased to call the *general* or *minister* of the Persians; and the *ship* has the motion of the piece to which we give the unaccountable appellation of *bishop*, but with a restriction which must greatly lessen its value.

In the *Purân* are next exhibited a few general rules and superficial directions for the conduct of the game. Thus, "the *pawns* and the *ship* both kill and may be voluntarily killed; while the *king*, the *elephant*, and the *horse*, may slay the foe, but must not expose themselves to be slain. Let each player preserve his own forces with extreme care, securing his *king* above all, and not sacrificing a superior to keep an inferior piece." Here (says the president) the commentator on the *Purân* observes, that the *horse*, who has the choice of *eight* moves from any central position, must be preferred to the *ship*, which has only the choice of *four*. But the argument would not hold in the common game, where the *bishop* and *tower* command a whole line, and where a knight is always of less value than a tower in action, or the bishop of that side on which the attack is begun. "It is by the overbearing power of the *elephant* (continues the *Purân*) that the king fights boldly; let the whole army, therefore, be abandoned in order to secure the *elephant*. The king must never place one *elephant* before another, unless he be compelled by want of room, for he would thus commit a dangerous fault; and if he can slay one of two hostile elephants, he must destroy that on his left hand."

All that remains of the passage which was copied for Sir William Jones relates to the several modes in which a partial success or complete victory may be obtained

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by any one of the four players; for, as in a dispute between two allies, one of the kings may sometimes assume the command of all the forces, and aim at a separate conquest. First, "When any one king has placed himself on the square of another king (which advantage is called *sinbasana* or the *throne*) he wins a stake, which is doubled if he kill the adverse monarch when he seizes his place; and if he can seat himself on the throne of his ally, he takes the command of the whole army." Secondly, "If he can occupy successively the thrones of all the three princes, he obtains the victory, which is named *cheturaji*; and the stake is doubled if he kill the last of the three, just before he takes possession of his throne; but if he kill him on his throne, the stake is quadrupled. Both in giving the *sinbasana* and the *cheturaji* the king must be supported by the *elephants*, or by all the forces united." Thirdly, "When one player has his own king on the board, but the king of his partner has been taken, he may replace his captive ally, if he can seize both the adverse kings; or if he cannot effect their capture, he may exchange his king for one of them, against the general rule, and thus redeem the allied prince, who will supply his place." This advantage has the name of *nripacrishta* or *recovered by the king*. Fourthly, "If a *pawn* can march to any square on the opposite extremity of the board, except that of the king, or that of the ship, he assumes whatever power belonged to that square." Here we find the rule, with a slight exception, concerning the advancement of *pawns*, which often occasions a most interesting struggle at our common chefs; but it appears that, in the opinion of one ancient writer on the Indian game, this privilege is not allowable when a player has three pawns on the board; but when only one pawn and one ship remains, the pawn may advance even to the square of a king or a ship, and assume the power of either. Fifthly, According to the people of *Lanèè*, where the game was invented, "there could be neither victory nor defeat if a king were left on the plain without force; a situation which they named *cacacasht'ha*." Sixthly, "If three ships happen to meet, and the fourth ship can be brought up to them in the remaining angle, this has the name of *vrihannauca*; and the player of the fourth seizes all the others."

The account of this game in the original Sanscrit is in verse, and there are two or three couplets still remaining, so very dark, either from an error in the manuscript, or from the antiquity of the language, that Sir William Jones could not understand the *Pandit's* explanation of them, and suspects that even to him they gave very indistinct ideas. It would be easy, however, he thinks, if it be judged worth while, to play at the game by the preceding rules; and a little practice would perhaps make the whole intelligible.

CHEVRETTE, in artillery, is an engine employed to raise guns or mortars into their carriage. It is formed of two pieces of wood about four feet long, standing upon a third, which is square. The uprights are about a foot asunder, and pierced with holes exactly opposite to one another, to receive a bolt of iron, which is put in, either higher or lower at pleasure, to serve as a support to a handspike, by which the gun is raised up.

By the author of the Military Guide, this is said to be the most useful of all the inventions for raising guns into their carriages; and it seems these inventions have been many.

CHICHA, the name given by the natives to the island of Jesso, which lies to the south of Oku-Jesso, or Segalian island. See **SEGALIAN** in this Supplement.

CHIMERE, the upper robe worn by bishops in church and in the House of Peers, to which the lawn sleeves are generally sewed. Before the Reformation, and even after it till the reign of Queen Elizabeth, the chimere was always of *scarlet silk*; but bishop Hooper, scrupling first at the robe itself, and then at the colour of it, as too light and gay for the episcopal gravity, the chimere was afterwards made of *black satin*. The archiepiscopal chimere has a long train.

CHIMNEY, a particular part of a house well known, which Professor Beckmann has, in our opinion, proved to be an invention comparatively modern. It would be very unfair dealing in us to give even a large abstract of one of the most curious dissertations of a curious book, which has been but lately published, and thereby injure the interest of him to whom the native of Britain is indebted for the pleasure of perusing it in his own tongue. No man, however, can blame us for here stating, in support of our own opinion, the professor's answer to the passage of Ferrari, which we have quoted under the word **CHIMNEY** in the Encyclopædia.

"When the triumph, says Appian*, caused those who had been proscribed by them to be sought for by the military, some of them, to avoid the bloody hands of their persecutors, hid themselves in wells, and others, as Ferrarius translates the words, *in fumaria sub tecto, qua scilicet fumus e tecto evolvoitur* (A). The true translation, however (says Mr Beckmann), is *fumosa cœnacula*. The principal persons of Rome endeavoured to conceal themselves in the smoky apartments of the upper story under the roof, which, in general, were inhabited only by poor people; and this seems to be confirmed by what Juvenal† expressly says, *Rarus venit in canacula* † *Sot. x. ver. 17.*

"Those passages of the ancients which speak of smoke rising up from houses, have with equal impropriety been supposed to allude to chimneys, as if the smoke could not make its way through doors and windows. Seneca‡ writes, 'Last evening I had some friends with me, and on that account a stronger smoke was raised; not such a smoke, however, as bursts forth from the kitchens of the great, and which alarms the watchmen, but such a one as signifies that guests are arrived.' Those whose judgments are not already warped by prejudice, will undoubtedly find the true sense of these words to be, that the smoke forced its way through the kitchen windows. Had the houses been built with chimney-funnels, one cannot conceive why the watchmen should have been alarmed when they observed a stronger smoke than usual arising from them; but as the kitchens had no conveniences of that nature, an apprehension of fire, when extraordinary entertainments were to be provided in the houses of the rich for large companies, seems to have been well founded; and on such occasions people appointed for that purpose were stationed

Chicha
Chimney.

(A) Ες καπηδεῖς ὑπαρῶσα, ἢ τῶν τεγῶν ταῖς κερᾶσι βυρμένας.

Chimney stationed in the neighbourhood to be constantly on the watch, and to be ready to extinguish the flames in case a fire should happen. There are many other passages to be found in Roman authors of the like kind, which it is hardly necessary to mention; such as that of Virgil*,

* Eclog. i. ver. 83.

‘ Et jam summa procul villarum culmina fumant,’

† *Aulular*, and the following words of Plautus†, descriptive of a miser :

‘ Quin divum atque hominum clamat continuo fidem,
‘ Suam rem periisse, seque eradicarier,
‘ De suo tigillo fumus si qua exit foras.’

In the *Vespe* of Aristophanes, referred to in the Encyclopædia, old Philocleon wishes to escape through the kitchen. Some one asks, “What is that which makes a noise in the chimney?” “I am the smoke (replies the old man), and am endeavouring to get out at the chimney.” “This passage, however (says the Professor), which, according to the usual translation, seems to allude to a common chimney, can, in my opinion, especially when we consider the illustration of the scholiasts, be explained also by a simple hole in the roof, as Reiske has determined; and indeed this appears to be more probable, as we find mention made of a top or covering‡ with which the hole was closed.”

In the Encyclopædia we have said, that the instances of chimneys remaining among the ruins of ancient buildings are few, and that the rules given by Vitruvius for building them are obscure; but we are now satisfied that there are *no* remains of ancient chimneys, and that Vitruvius gives *no* rules, either obscure or perspicuous, for building what, in the modern acceptation of the word, deserves the name of a chimney.

“The ancient mason-work still to be found in Italy does not determine the question. Of the walls of towns, temples, amphitheatres, baths, aqueducts, and bridges, there are some though very imperfect remains, in which chimneys cannot be expected; but of common dwelling-houses none are to be seen except at Herculaneum, and there no traces of chimneys have been discovered. The paintings and pieces of sculpture which are preserved afford us as little information; for nothing can be perceived in them that bears the smallest resemblance to a modern chimney.”

“If there were no funnels in the houses of the ancients to carry off the smoke, the directions given by Columella, to make kitchens so high that the roof should not catch fire, was of the utmost importance. An accident of the kind, which that author seems to have apprehended, had almost happened at Beneventum, when the landlord who entertained Mæcenas and his company was making a strong fire in order to get some birds sooner roasted.

‘ ————— ubi sedulus hospes
‘ Pæne arsit, macros dum turdos versat in igne;
‘ Nam vaga per veterem dilapso flamma culinam
‘ Vulcano summum properabat lambere tectum §.’

§ Horat.

lib. i. sat. 5.

Had there been chimneys in the Roman houses, Vitruvius certainly would not have failed to describe their construction, which is sometimes attended with considerable difficulties, and which is intimately connected with the regulation of the plan of the whole edifice. He does not, however, say a word on this subject; neither

does Julius Pollux, who has collected with great care the Greek names of every part of a dwelling-house; and Grapaldus, who in later times made a collection of the Latin terms, has not given a Latin word expressive of a modern chimney*.”

* Francis Marii Græni de partibus ædium libri.

Our author admits the derivation of the word *chimney* to be as we have given it in the Encyclopædia; but (say he) “*Caminus* signified, as far as I have been able to learn, first a chemical or metallurgic furnace, in which a crucible was placed for melting and refining metals; secondly, a smith’s forge; and, thirdly, a hearth on which portable stoves or fire-pans were placed for warming the apartment. In all these, however, there appears no trace of a chimney.” Herodotus relates (lib. viii. c. 137.), that a king of Libya, when one of his servants asked for his wages, offered him in jest the sun, which at that time shone into the house through an opening in the roof, under which the fire was perhaps made in the middle of the edifice. If such a hole must be called a chimney, our author admits that chimneys were in use among the ancients, especially in their kitchens; but it is obvious that such chimneys bore no resemblance to our’s, through which the sun could not dart his rays upon the floor of any apartment.

“However imperfect may be the information which can be collected from the Greek and Roman authors respecting the manner in which the ancients warmed their apartments, it nevertheless shews that they commonly used for that purpose a large fire-pan or portable stove, in which they kindled wood, and, when the wood was well lighted, carried it into the room, or which they filled with burning coals. When Alexander the Great was entertained by a friend in winter, as the weather was cold and raw, a small fire basin was brought into the apartment to warm it. The prince, observing the size of the vessel, and that it contained only a few coals, desired his host, in a jeering manner, to bring more wood or frankincense; giving him thus to understand that the fire was fitter for burning perfumes than to produce heat. Anacharis, the Scythian philosopher, though displeas’d with many of the Grecian customs, praised the Greeks, however, because they shut out the smoke and brought only fire into their houses †. We are informed by Lampridius, that the extravagant Hellogabalus caused to be burned in these stoves, instead of wood, Indian spices and costly perfumes ‡. It is also worthy of notice, that coals were found in some of the apartments of Herculaneum, as we are told by Winklemann, but neither stoves nor chimneys.”

† Plutarch. Sympof. lib. vi. 7. p. 692.
‡ Æl. Lamprid. Vita Heliogab. cap. 31.

It is well known to every scholar, that the useful arts of life were invented in the east, and that the customs, manners, and furniture of eastern nations, have remained from time immemorial almost unchanged. In Persia, which the late Sir William Jones seems to have considered as the original country of mankind, the methods employed by the inhabitants for warming themselves have a great resemblance to those employed by the ancient Greeks and Romans for the same purpose. According to De la Valle, the Persians make fires in their apartments, not in chimneys as we do, but in stoves in the earth, which they call *tennor*. “These stoves consist of a square or round hole, two spans or a little more in depth, and in shape not unlike an Italian cask. That this hole may throw out heat sooner, and with more strength, there is placed in it an iron vessel of the

Chimney. same size, which is either filled with burning coals, or a fire of wood and other inflammable substances is made in it. When this is done, they place over the hole or stove a wooden top, like a small low table, and spread above it a large coverlet quilted with cotton, which hangs down on all sides to the floor. This covering condenses the heat, and causes it to warm the whole apartment. The people who eat or converse there, and some who sleep in it, lie down on the floor above the carpet, and lean, with their shoulders against the wall, on square cushions, upon which they sometimes also sit; for the *tennor* is constructed in a place equally distant from the walls on both sides. Those who are not very cold only put their feet under the table or covering; but those who require more heat can put their hands under it, or creep under it altogether. By these means the stove diffuses over the whole body, without causing uneasiness to the head, so penetrating and agreeable a warmth, that I never in winter experienced any thing more pleasant. Those, however, who require less heat let the coverlet hang down on their side to the floor, and enjoy without any inconvenience from the stove the moderately heated air of the apartment. They have a method also of stirring up or blowing the fire when necessary, by means of a small pipe united with the tennor or stove under the earth, and made to project above the floor as high as one chooses; so that the wind, when a person blows into it, because it has no other vent, acts immediately upon the fire like a pair of bellows. When there is no longer occasion to use this stove, both holes are closed up, that is to say, the mouth of the stove and that of the pipe which conveys the air to it, by a flat stone made for that purpose. Scarcely any appearance of them is then to be perceived, nor do they occasion inconvenience, especially in a country where it is always customary to cover the floor with a carpet, and where the walls are plastered. In many parts these ovens are used to cook victuals, by placing kettles over them. They are employed also to bake bread; and for this purpose they are covered with a large broad metal plate, on which the cake is laid; but if the bread is thick and requires more heat, it is put into the stove itself."

Our learned author having proved, to our entire satisfaction, that chimneys, such as we have now in every comfortable room, were unknown to the most polished nations of antiquity, sets himself to inquire into the era of their invention; and the oldest account of them which he finds is an inscription at Venice, which relates, that in the year 1347 a great many chimneys were thrown down by an earthquake. It would appear, however, that in some places they had been in use for a considerable time before that period; for *De Gataris*, in his History of Padua, relates, that *Francesco de Carraro*, lord of Padua, came to Rome in 1368, and finding no chimneys in the inn where he lodged, because at that time fire was kindled in a hall in the middle of the floor, he caused two chimneys like those which had long been used at Padua to be constructed by masons and carpenters, whom he had brought along with him. Over these chimneys, the first ever seen at Rome, he affixed his arms, which were still remaining in the time of *De Gataris*, who died of the plague in 1405.

Though chimneys have been thus long in use, they are yet far enough from being brought to perfection.

There is hardly a modern house, especially if highly finished, in which there is not one room at least liable to be filled with smoke when it is attempted to be heated by an open fire; and there are many houses so infested with this plague as to be almost uninhabitable during the winter months; not to mention other great defects in common chimneys, which not being so obvious have attracted less attention. Many ingenious methods have been proposed to cure smokey chimneys in every situation (see *SMOKE*, *Encycl.*); but Count Rumford's Essay on this subject contains the most valuable directions that we have seen, not only for removing the inconvenience of smoke, but likewise for increasing the heat of the room by a diminished consumption of fuel.

To those who are at all acquainted with the nature and properties of elastic fluids, it must be obvious, that the whole mystery of curing smokey chimneys consists in finding out and removing the accidental causes which prevent the heated smoke from being forced up the chimney by the pressure of the cool and therefore heavier air of the room. Though these causes are various, yet, says our author, that which will most commonly be found to operate, is the bad construction of the chimney in the neighbourhood of the fire-place. "The great fault of all the open fire-places or chimneys for burning wood or coals in an open fire now in common use is, that they are much too large; or rather it is the throat of the chimney, or the lower part of its open canal, in the neighbourhood of the mantle, and immediately over the fire, which is too large."

To this fault, therefore, the attention should be first turned in every attempt which is made to improve the construction of chimneys; for however perfect a fire-place may be in other respects, if the opening left for the passage of the smoke is larger than is necessary for that purpose, nothing can prevent the warm air of the room from escaping through it; and whenever this happens, there is not only an unnecessary loss of heat, but the warm air which leaves the room to go up the chimney being replaced by cold air from without, draughts of cold air cannot fail to be produced in the room, to the great annoyance of those who inhabit it. But although both these evils may be effectually remedied by reducing the throat of the chimney to a proper size, yet in doing this several precautions will be necessary. And first of all, the throat of the chimney should be in its proper place; that is to say, in that place in which it ought to be, in order that the ascent of the smoke may be most facilitated: now as the smoke and hot vapour which rise from a fire naturally tend upwards, the proper place for the throat of the chimney is evidently perpendicularly over the fire.

But there is another circumstance to be attended to in determining the proper place for the throat of a chimney, and that is, to ascertain its distance from the fire, or how far above the burning fuel it ought to be placed. In determining this point there are many things to be considered, and several advantages and disadvantages to be weighed and balanced.

As the smoke and vapour which ascend from burning fuel rise in consequence of their being rarefied by heat, and made lighter than the air of the surrounding atmosphere; and as the degree of their rarefaction, and consequently their tendency to rise, is in proportion to the intensity of their heat; and further, as they are hot-

Chimney ter near the fire than at a greater distance from it—it is clear that the nearer the throat of a chimney is to the fire, the stronger will be what is commonly called its draught, and the less danger there will be of its smoking. But, on the other hand, when the draught of a chimney is very strong, and particularly when this strong draught is occasioned by the throat of the chimney being very near the fire, it may so happen that the draught of air into the fire may become so strong as to cause the fuel to be consumed too rapidly. There are likewise several other inconveniences which would attend the placing of the throat of a chimney *very near* the burning fuel.

The position of the throat of a chimney being once determined, the next points to be ascertained are its size and form, and the manner in which it ought to be connected with the fire-place below, and with the open canal of the chimney above. But as these investigations are intimately connected with those which relate to the form proper to be given to the fire-place itself, we must consider them all together.

Now the design of a chimney fire being simply to warm a room, it is necessary, first of all, to contrive matters so that the room shall be actually warmed; secondly, that it be warmed with the smallest expence of fuel possible; and, thirdly, that in warming it, the air of the room be preserved perfectly pure, and fit for respiration, and free from smoke and all disagreeable smells.

To determine in what manner a room is heated by an open chimney fire, it will be necessary first of all to find out *under what form* the heat generated in the combustion of the fuel exists, and then to see how it is communicated to those bodies which are heated by it.

In regard to the first of these subjects of inquiry, it is quite certain that the heat which is generated in the combustion of the fuel exists under *two* perfectly distinct and very different forms. One part of it is *combined* with the smoke, vapour, and heated air which rise from the burning fuel, and goes off with them into the upper regions of the atmosphere; while the other part, which appears to be *uncombined*, or, as some ingenious philosophers have supposed, combined only with light, and therefore called *radiant heat*, is sent off from the fire in rays in all possible directions.

With respect to the second subject of inquiry, namely, how this heat, existing under these two different forms, is communicated to other bodies, it is highly probable that the combined heat can only be communicated to other bodies by *actual contact* with the body with which it is combined; and with regard to the rays which are sent off by burning fuel, it is certain that *they* communicate or generate heat only *when* and *where* they are stopped or absorbed. In passing through air, which is transparent, they certainly do not communicate any heat to it; and it seems highly probable that they do not communicate heat to solid bodies by which they are reflected.

As it is the radiant heat alone which can be employed in warming a room, when fuel is burnt for this purpose in an open fire-place, it becomes an object of much importance to determine how the greatest quantity of it may be generated in the combustion of the fuel, and how the greatest proportion possible of that generated may be brought into the room.

Now the quantity of radiant heat generated in the combustion of a given quantity of any kind of fuel depends very much upon the management of the fire, or upon the manner in which the fuel is consumed. When the fire burns bright, much radiant heat will be sent off from it; but when it is *smothered up*, very little will be generated, and indeed very little combined heat that can be employed to any useful purpose: most of the heat produced will be immediately *expended* in giving elasticity to a thick dense vapour or smoke, which will be seen rising from the fire; and the combustion being very incomplete, a great part of the inflammable matter of the fuel being merely rarefied and driven up the chimney without being inflamed, the fuel will be wasted to little purpose. And hence it appears of how much importance it is, whether it be considered with a view to economy, or to cleanliness, comfort, and elegance, to pay due attention to the management of a chimney fire.

Nothing can be more perfectly void of common sense, and wasteful and slovenly at the same time, than the manner in which chimney fires, and particularly where coals are burned, are commonly managed by servants. They throw on a load of coals at once, through which the flame is hours in making its way; and frequently it is not without much trouble that the fire is prevented from going quite out. During this time no heat is communicated to the room; and what is still worse, the throat of the chimney being occupied merely by a heavy dense vapour, not possessed of any considerable degree of heat, and consequently not having much elasticity, the warm air of the room finds less difficulty in forcing its way up the chimney and escaping than when the fire burns bright. And it happens not unfrequently, especially in chimneys and fire-places ill-constructed, that this current of warm air from the room which presses into the chimney, crossing upon the current of heavy smoke which rises slowly from the fire, obstructs it in its ascent, and beats it back into the room: hence it is that chimneys so often smoke when too large a quantity of fresh coals is put upon the fire. So many coals should never be put on the fire at once as to prevent the free passage of the flame between them. In short, a fire should never be smothered; and when proper attention is paid to the quantity of coals put on, there will be very little use for the poker; and this circumstance will contribute very much to cleanliness, and to the preservation of furniture.

As we have seen what is necessary to the *generation* of the greatest quantity of radiant heat, it remains to be determined how the greatest proportion of that which is generated and sent off from the fire in all directions may be made to *enter the room*, and assist in warming it.

This must be done, first, by causing as many as possible of the rays, as they are sent off from the fire in straight lines, to come *directly* into the room; which can only be effected by bringing the fire as far forward as possible, and leaving the opening of the fire-place as wide and as high as can be done without inconvenience: and, secondly, by making the sides and back of the fire-place of such a form, and constructing them of such materials, as to cause the direct rays from the fire, which strike against them, to be sent into the room by reflection in the greatest abundance.

Now it will be found upon examination, that the best

Chimney. form for the vertical sides of a fire-place, or the *covings* (as they are called), is that of an upright plane, making an angle with the plane of the back of the fire-place of about 135 degrees.—According to the present construction of chimneys, this angle is sometimes only 90, and very seldom above 100 or 110 degrees; but it is obvious, that in all these cases the two sides or coverings of the fire-place are very ill-contrived for throwing into the room by reflection the rays from the fire which fall upon them.

With regard to the materials which should be employed in the construction of fire-places, particularly the backs and covings, it is obvious that those are to be preferred which *absorb* the *least*, and of course *reflect* the greatest quantity of radiant heat. Iron, therefore, and, in general, metals of all kinds, are the very worst materials which can possibly be employed for the backs and covings of chimneys; whilst fire-stone white-washed, or common bricks and mortar, covered with a thin coating of plaster, and white-washed, answer the purpose extremely well. A white colour should, indeed, be always given to the inside of a chimney of whatever materials it be constructed; and black, which is at present so common, should be carefully avoided, because white reflects the most, and black the least, radiant heat. The grate, however, cannot well be made of any thing else than iron; but there is no necessity whatever for that immense quantity of iron which surrounds grates as they are commonly fitted up, and which not only renders them very expensive, but essentially injures the fire-place.

To have only pointed out the faults of the chimneys in use, without shewing how these faults may be corrected, would have been a work of very little value; but the Count's Treatise is complete, and contains the plainest directions for the construction of fire-places. These directions are introduced by an explanation of some technical words and expressions. Thus, by the *throat* of a chimney, already mentioned, he means the lower extremity of its canal, where it unites with the upper part of its open fire-place. This throat is commonly found about a foot above the level of the lower part of the mantle, and it is sometimes contracted to a smaller size than the rest of the canal of the chimney, and sometimes not.

Plate XX. Fig. 1. shews the section of a chimney on the common construction, in which *de* is the throat.

Fig. 2. shews the section of the same chimney altered and improved, in which *di* is the reduced throat.

The *breast* of a chimney is that part of it which is immediately behind the mantle. It is the wall which forms the entrance from below into the throat of the chimney in front, or towards the room. It is opposite to the upper extremity of the back of the open fire-place, and parallel to it: in short, it may be said to be the back part of the mantle itself.—In the figures 1. and 2. it is marked by the letter *d*. The width of the throat of the chimney (*de* fig. 1. and *di* fig. 2.) is taken from the breast of the chimney to the back, and its length is taken at right angles to its width, or in a line parallel to the mantle (*a* fig. 1. and 2.).

The bringing forward of the fire into the room, or rather bringing it nearer to the front of the opening of the fire-place, and the diminishing of the throat of the chimney, being two objects principally had in view in

the alterations in fire-places proposed by the Count, it is evident that both these may be attained merely by bringing forward the back of the chimney. The only question therefore is, How far it should be brought forward? The answer is short, and easy to be understood; bring it forward as far as possible, without diminishing too much the passage which must be left for the smoke. Now as this passage, which in its narrowest part he calls *the throat of the chimney*, ought, for reasons which have been already explained, to be immediately, or perpendicularly over the fire, it is evident that the back of the chimney must always be built perfectly upright. To determine, therefore, the place for the new back, or how far precisely it ought to be brought forward, nothing more is necessary than to ascertain how wide the throat of the chimney ought to be left, or what space must be left between the top of the breast of the chimney where the upright canal of the chimney begins, and the new back of the fire-place carried up perpendicularly to that height.

Numerous experiments have convinced the Count, that, all circumstances being well considered, and the advantages and disadvantages compared and balanced, *four inches* is the best width that can be given to the throat of a chimney, whether the fire-place be destined to burn wood, coals, turf, or any other fuel. In very large halls where great fires are kept up, it may sometimes, though very rarely, be proper to increase this width to four inches and a half, or even to five inches.

The next thing to be considered is the width which it will be proper to give to the back of the chimney; and, in most cases, this should be *one-third* of the width of the opening of the fire place in front. It is not indeed absolutely necessary to conform with rigour to this decision, nor is it always possible; but it should invariably be conformed to as far as circumstances will permit. Where a chimney, says the Count, is designed for warming a room of a middling size, and where the thickness of the wall of the chimney in front, measured from the front of the mantle to the breast of the chimney, is nine inches, I should set off four inches more for the width of the throat of the chimney, which, supposing the back of the chimney to be built upright, as it always ought to be, will give thirteen inches for the depth of the fire-place, measured upon the hearth, from the opening of the fire-place in front to the back. In this case, thirteen inches would be a good size for the width of the back; and three times thirteen inches, or 39 inches, for the width of the opening of the fire-place in front; and the angle made by the back of the fire-place and the sides of it, or covings, would be just 135 degrees, which is the best position they can have for throwing heat into the room. This position, indeed, it may sometimes be impossible to attain in altering chimneys already built; but a deviation from it of two or three degrees will be of no great consequence; for the points of by much the greatest importance in altering fire-places upon the principles here recommended, are the bringing forward the back to its proper place, and making it of the proper width.

Provision, however, must be made for the passage of the chimney-sweeper up the chimney; and this may easily be done in the following manner: In building up the new back of the fire-place; when this wall (which need never be more than the width of a single brick

Chimney. brick in thickness) is brought up so high that there remains no more than about ten or eleven inches between what is then the top of it and the inside of the mantle, or lower extremity of the breast of the chimney, an opening or door-way, eleven or twelve inches wide, must be begun in the middle of the back, and continued quite to the top of it, which, according to the height to which it will commonly be necessary to carry up the back, will make the opening abundantly sufficient to let the chimney-sweeper pass. When the fire-place is finished, this door-way is to be closed by a tile or fit piece of stone placed in it without mortar, and by means of a rabbit made in the brick-work, confined in its place in such a manner as that it may be easily removed when the chimney is to be swept, and restored to its place when that work is over. Of this contrivance the reader will be able to form a clear conception from fig. 2. which represents the section of a chimney after it has been properly altered from what is exhibited in fig. 1. In this improved chimney *kl* is the new back of the fire-place; *li* the tile or stone which closes the door-way for the chimney-sweeper; *di* the throat of the chimney narrowed to four inches; *a* the mantle, and *b* the stone placed under the mantle, supposed to have been too high, in order to diminish the height of the opening of the fire-place in front.

It has been observed above, that the new back, which it will always be found necessary to build in order to bring the fire sufficiently forward, in altering a chimney constructed on the common principles, need never be thicker than the width of a common brick. The same may be said of the thickness necessary to be given to the new sides or coverings of the chimney; or if the new back and coverings are constructed of stone, one inch and three quarters, or two inches in thickness, will be sufficient. Care should be taken in building up these new walls to unite the back to the coverings in a solid manner.

Whether the new back and coverings are constructed of stone or built of bricks, the space between them and the old back and coverings of the chimney ought to be filled up, to give greater solidity to the structure. This may be done with loose rubbish, or pieces of broken bricks or stones, provided the work be strengthened by a few layers or courses of bricks laid in mortar; but it will be indispensably necessary to finish the work where these new walls end, that is to say, at the top of the throat of the chimney, where it ends abruptly in the open canal of the chimney, by a horizontal course of bricks well secured with mortar. This course of bricks will be upon a level with the top of the door-way left for the chimney-sweeper; and the void behind the door-way must be covered with a horizontal stone or tile, to be removed at the same time the door is removed, and for the same purpose.

From these descriptions it is clear, that where the throat of the chimney has an end, that is to say, where it enters into the lower part of the open canal of the chimney, there the three walls which form the two coverings and the back of the fire-place all end abruptly. It is of much importance that they should end in this manner; for were they to be sloped outward, and raised in such a manner as to swell out the upper extremity of the throat of the chimney in the form of a trumpet, and increase it by degrees to the size of the canal

Chimney. of the chimney, this manner of uniting the lower extremity of the canal of the chimney with the throat would tend to assist the winds, which may attempt to blow down the chimney, in forcing their way through the throat, and throwing the smoke backward into the room; but when the throat of the chimney ends abruptly, and the ends of the new walls form a flat horizontal surface, it will be much more difficult for any wind from above to find and force its way through the narrow passage of the throat of the chimney.

As the two walls which form the new coverings of the chimney are not parallel to each other, but inclined, presenting an oblique surface towards the front of the chimney, and as they are built perfectly upright, and quite flat, from the hearth to the top of the throat, where they end, it is evident that an horizontal section of the throat will not be an oblong square; but its deviation from that form is a matter of no consequence; and no attempts should ever be made, by twisting the coverings above where they approach the breast of the chimney, to bring it to that form. All twists, bends, prominences, excavations, and other irregularities of form in the coverings of a chimney, never fail to produce eddies in the current of air which is continually passing into, and through, an open fire-place in which a fire is burning; and all such eddies disturb either the fire or the ascending current of smoke, or both; and not unfrequently cause the smoke to be thrown back into the room. Hence it appears, that the coverings of chimneys should never be made circular, or in the form of any other curve, but always quite flat.

For the same reason, that is to say, to prevent eddies, the breast of the chimney, which forms that side of the throat that is in front or nearest to the room, should be neatly cleaned off, and its surface made quite regular and smooth. This may be easily done by covering it with a coat of plaster, which may be made thicker or thinner in different parts, as may be necessary in order to bring the breast of the chimney to be of the proper form.

With regard to the form of the breast of a chimney, this is a matter of very great importance, and which ought always to be particularly attended to. The worst form it can have is that of a vertical plane or upright flat; and next to this the worst form is an inclined plane. Both these forms cause the current of warm air from the room, which will, in spite of every precaution, sometimes find its way into the chimney, to cross upon the current of smoke which rises from the fire in a manner most likely to embarrass it in its ascent, and drive it back.

The current of air which, passing under the mantle, gets into the chimney, should be made *gradually to bend its course upwards*; by which means it will unite *quietly* with the ascending current of smoke, and will be less likely to check it, or force it back into the room. Now this may be effected with the greatest ease and certainty, merely by *rounding off* the breast of the chimney or back part of the mantle, instead of leaving it flat or full of holes and corners; and this of course ought always to be done.

Having thus ascertained the form and position of the new coverings, the ingenious author next turns his attention to the height to which they should be carried. This will depend not only on the height of the mantle,

but

Chimney. but also, and more especially, on the height of the breast of the chimney, or of that part of the chimney where the breast ends and the upright canal begins.—The back and coverings must rise a few inches, five or six for instance, higher than this part, otherwise the throat of the chimney will not be properly formed; but no advantage would be gained by carrying them higher.

One important circumstance respecting chimney fire-places still remains to be considered; and that is the grate. In placing the grate, the thing principally to be attended to is, to make the back of it coincide with the back of the fire place. But as many of the grates now in common use will be found to be too large, when the fire places are altered and improved, it will be necessary to diminish their capacities by filling them up at the back and sides with pieces of fire stone. When this is done, it is the front of the flat piece of fire-stone which is made to form a new back to the grate, which must be made to coincide with, and make part of the back of the fire-place.—But in diminishing the capacities of grates with pieces of fire-stone, care must be taken not to make them *too narrow*.

The proper width for grates destined for rooms of a middling size will be from six to eight inches, and their length may be diminished more or less according as the room is heated with more or less difficulty, or as the weather is more or less severe.—But where the width of a grate is not more than five inches it will be very difficult to prevent the fire from going out.

It frequently happens that the iron backs of grates are not vertical, or upright, but inclined backwards.—When these grates are so much too wide as to render it necessary to fill them up behind with fire-stone, the inclination of the back will be of little consequence; for by making the piece of stone with which the width of the grate is to be diminished in the form of a wedge, or thicker above than below, the front of this stone, which in effect will become the back of the grate, may be made perfectly vertical; and the iron back of the grate being hid in the solid work of the back of the fire-place, will produce no effect whatever; but if the grate be already so narrow as not to admit of any diminution of its width, in that case it will be best to take away the iron back of the grate entirely, and fixing the grate firmly in the brick-work, cause the back of the fire-place to serve as a back to the grate.

Where grates, which are designed for rooms of a middling size, are longer than 14 or 15 inches, it will always be best, not merely to diminish their lengths, by filling them up at their two ends with fire-stone, but, forming the back of the chimney of a proper width, without paying any regard to the length of the grate, to carry the coverings through the two ends of the grate in such a manner as to conceal them, or at least to conceal the back corners of them in the walls of the coverings.

Had these directions been duly attended to by the masons who in Scotland pretend to alter chimneys on the principles of Count Rumford, we should not have observed so many of the grates placed by them jutting out beyond the mantle of the chimney; nor of course heard so many complaints of rooms being rendered more

Chimney. smokey, and the consumption of fuel increased by these pretended improvements. But when the grate is not set in its proper place, when its sloping iron back is retained, when no pains have been taken to make its ends coincide with the coverings of the fire-place, when the mantle, instead of having its back rounded off, is a vertical plane of iron cutting the column of smoke which rises beneath it, and, above all, when the throat of the chimney, instead of four, is made, as we often see, fourteen inches wide; let it be remembered, that not one of Count Rumford's directions has been followed, and that his principles have as little to do with the construction of such a chimney as with the building of the wall of China or the pyramids of Egypt.

To contribute our aid to prevent these blunders for the future, we shall here subjoin the Count's directions for laying out the work; not to instruct masons and bricklayers, to whom we earnestly recommend the study of the essay itself (B), which contains much valuable information that we have omitted; but merely to give the country gentleman an opportunity of discovering whether the workmen whom he employs deviates far and needlessly from the principles which he pretends to follow.

When a chimney is to be altered, after taking away the grate and removing the rubbish, first draw a straight line with chalk, or with a lead pencil, upon the hearth, from one jamb to the other,—even with the front of the jambs. The dotted line A B, fig. 3. may represent this line.

From the middle *c* of this line, (A B) another line *c d* is to be drawn perpendicular to it, across the hearth, to the middle *d*, of the back of the chimney.

A person must now stand upright in the chimney, with his back to the back of the chimney, and hold a plumb-line to the middle of the upper part of the breast of the chimney (*d*, fig. 1.), or where the canal of the chimney begins to rise perpendicularly;—taking care to place the line above in such a manner that the plumb may fall on the line *c d* (fig. 3.) drawn on the hearth from the middle of the opening of the chimney in front to the middle of the back, and an assistant must mark the precise place *e*, on that line where the plumb falls.

This being done, and the person in the chimney having quitted his station, four inches are to be set off on the line *c d*, from *e*, towards *d*; and the point *f*, where these four inches end, (which must be marked with chalk, or with a pencil), will show how far the new back is to be brought forward.

Through *f*, draw the line *g b* parallel to the line A B, and this line *g b* will show the direction of the new back, or the ground line upon which it is to be built. The line *c f* will show the depth of the new fire-place; and if it should happen that *c f* is equal to about *one-third* of the line A B, and if the grate can be accommodated to the fire-place, instead of its being necessary to accommodate the fire place to the grate; in that case, half the length of the line *c f* is to be set off from *f* on the line *g f b*, on one side to *k*, and on the other to *i*, and the line *i k* will show the ground line of the fore part of the back of the chimney.

In all cases where the width of the opening of the fire-place in front (A B) happens to be not greater, or
not

(B) It costs but two shillings; and he must be a poor bricklayer indeed who cannot afford to pay that sum for instruction in the most important, as well as most difficult, part of his business.

Chimney. not more than two or three inches greater than *three* times the width of the new back of the chimney (*ik*), this opening may be left; and lines drawn from *i* to *A*, and from *k* to *B*, will show the width and position of the front of the new covings;—but when the opening of the fire-place in front is still wider, it must be reduced; which is to be done in the following manner:

From *c*, the middle of the line *AB*, *ca* and *cb* must be set off equal to the width of the back (*ik*), added to half its width (*fi*); and lines drawn from *i* to *a*, and from *k* to *b*, will show the ground plan of the fronts of the new covings.

When this is done, nothing more will be necessary than to build up the back and covings; and if the fire-place is designed for burning coals, to fix the grate in its proper place, according to the directions already given.—When the width of the fire-place is reduced, the edges of the covings *aA* and *bB* are to make a finish with the front of the jambs.—And in general it will be best, not only for the sake of the appearance of the chimney, but for other reasons also, to lower the height of the opening of the fire-place whenever its width in front is diminished.

A front view of the chimney, after it has been thus altered, is exhibited in fig. 4. where the under part of the door-way is represented, as closed by the white dotted lines.

When the wall of the chimney in front, measured from the upper part of the breast of the chimney to the front of the mantle, is very thin, it may happen, and especially in chimneys designed for burning wood upon the hearth, or upon dogs, that the depth of the chimney, determining according to the directions here given, may be too small.

Thus, for example, supposing the wall of the chimney, in front, from the upper part of the breast of the chimney to the front of the mantle, to be only four inches, (which is sometimes the case, particularly in rooms situated near the top of a house), in this case, if we take four inches for the width of the throat, this will give eight inches only for the depth of the fire-place, which would be too little, even were coals to be burnt instead of wood.—In this case (says the Count) I should increase the depth of the fire-place at the hearth to 12 or 13 inches, and should build the back perpendicular to the height of the top of the burning fuel (whether it be wood burnt upon the hearth or coals in a grate); and then, sloping the back by a gentle inclination forward, bring it to its proper place, that is to say, *perpendicularly under the back part of the throat of the chimney*. This slope, (which will bring the back forward four or five inches, or just as much as the depth of the fire-place is increased), though it ought not to be too abrupt, yet it ought to be quite finished at the height of eight or ten inches above the fire, otherwise it may perhaps cause the chimney to smoke; but when it is very near the fire, the heat of the fire will enable the current of rising smoke to overcome the obstacle which this slope will oppose to its ascent, which it could not do so easily were the slope situated at a greater distance from the burning fuel.

Fig. 5, 6, and 7, show a plan, elevation, and section of a fire-place constructed or altered upon this principle.—The wall of the chimney in front at *a*, fig. 7. being

only four inches thick, four inches more added to it for the width of the throat would have left the depth of the fire-place measured upon the hearth *bc* only eight inches, which would have been too little;—a niche *c* and *e* was therefore made in the new back of the fire-place for receiving the grate, which niche was six inches deep in the centre of it, below 13 inches wide, (or equal in width to the grate,) and 23 inches high; finishing above with a femicircular arch, which, in its highest part, rose seven inches above the upper part of the grate.—The door-way for the chimney-sweeper, which begins just above the top of the niche, may be seen distinctly in both the figures 6 and 7.—The space marked *g*, fig. 7. behind this door-way, may either be filled with loose bricks, or may be left void.—The manner in which the piece of stone *f*, fig. 7. which is put under the mantle of the chimney to reduce the height of the opening of the fire-place, is rounded off on the inside in order to give a fair run to the column of smoke in its ascent through the throat of the chimney, is clearly expressed in this figure. The plan fig. 5. and elevation fig. 6. show how much the width of the opening of the fire-place in front is diminished, and how the covings in the new fire-place are formed.

A perfect idea of the form and dimension of the fire-place in its original state, as also after its alteration, may be had by a careful inspection of these figures.

In chimneys, like that represented in figure 8, where the jambs *A* and *B* project far into the room, and where the front edge of the marble slab *o*, which forms the coving, does not come so far forward as the front of the jambs, the workmen in constructing the new covings are very apt to place them,—not in the line *cA*, which they ought to do,—but in the line *co*, which is a great fault.—The covings of a chimney should never range *behind* the front of the jambs, however those jambs may project into the room;—but it is not absolutely necessary that the covings should *make a finish* with the internal front corners of the jambs, or that they should be continued from the back *c*, quite to the front of the jambs at *A*.—They may finish in front at *a* and *b*; and small corners *A, o, a*, may be left for placing the shovels, tongs, &c.

Were the new coving to range with the front edge of the old coving *o*, the obliquity of the new coving would commonly be too great;—or the angle *dc o* would exceed 135 degrees, *which it never should do*,—or at least never be more than a very few degrees. No inconvenience of any importance will arise from making the obliquity of the covings *less* than what is here recommended; but many cannot fail to be produced by making it much greater.

These extracts, which we have made so liberally from Count Rumford's essay on chimney fire-places, will be sufficient, we hope, to bring fully within the comprehension of those who are acquainted with pneumatics and pneumatic chemistry the principles on which chimneys and fire-places should be constructed; but such as are in a great measure strangers to these sciences will do well to consult the essay itself. With a benevolence which does him honour, the ingenious author has expressed a wish that his doctrines on this important subject may be widely propagated; and to encourage artists to study them, he has declared to the public in general, "that as he does not intend to take out himself,

Chimney-Sweepers.

or to suffer others to take out, any patent for any invention of his which may be of public utility, all persons are at full liberty to imitate them, and vend them, for their own emolument, when and where, and in any way they may think proper."

CHIMNEY-Sweepers are a class of men who earn their subsistence by clearing chimneys of soot, which occasions them to smoke. While chimneys continued to be built in so simple a manner, and of such a width as they are still observed to be in old houses, they were so easily cleaned that this service could be performed by a servant with a wisp of straw, or a little brushwood fastened to a rope; but after the flues, in order to save room, were made narrower, or when several flues were united together, the cleaning of them became so difficult, that they required boys, or people of small size, accustomed to that employment. The first chimney-sweepers in Germany came from Savoy, Piedmont, and the neighbouring territories. These for a long time were the only countries where the cleaning of chimneys was followed as a trade; and hence Professor Beckmann concludes with great probability, that chimneys were invented in Italy. The Lotharingians, however, undertook the business of chimney-sweeping also; on which account the duke of Lotharingia was styled the *imperial fire-master*. The first Germans who condescended to clean chimneys were miners; and the chimney-sweepers in that empire still procure their boys from the forest of Hartz, where the greatest mines are wrought. Very lately, and perhaps at present, the greater part of the chimney-sweepers in Paris were Savoyards, many of them not above eight years of age, who, for the paltry sum of five sous, which they were obliged to share with their avaricious master, would scramble, at the hazard of their lives, through a narrow funnel fifty feet in length, and with their besoms clean it from soot and dirt. At what precise period chimney-sweeping became a trade in England and Scotland, we have not been able to learn; but among us, as well as elsewhere, young boys are employed in this business, who are said to be very harshly treated by fellows who stole them from the doors of cottages in the country. That children have been sometimes kidnapped by chimney-sweepers, we can have no doubt; but that the practice is frequent, we do not believe. We think however that the business might be wholly abolished; for a narrow funnel might certainly, if not very crooked, be swept by a bundle of straw or brushwood fastened to a rope, as well as one that is wider: and the bricks which separate the contiguous flues we know to be less injured by this method of sweeping, when cautiously gone about, than by sending boys up the chimneys.

On the 4th July 1796, letters patent were granted to Daniel Davis, of the parish of St Giles, Middlesex, for his invention of a machine, by which he proposes to sweep and cleanse chimneys, and extinguish chimneys on fire, without any person going up the same, as is now the practice. The machine consists of an apparatus of rack-work, of various lengths, which, by means of a hand-turn, is made to ascend the chimney. The lengths of the rack-work are joined together by means of mortices and tenons, with a spring which holds them fast. In each length is a joint, by which the rack-work will accommodate itself to angles or turns in the flues. To the first or uppermost length

is fixed a brush of hair, or wire, or sponge, or other elastic substance as the occasion may require. China.

This invention is doubtless well calculated to answer the purpose intended, and may perhaps be the means of diminishing the number of those objects of misery, the unfortunate chimney-sweepers.

CHINA is an empire of such antiquity and extent, the laws and customs of the people are so singular, and the populousness of the country so very great—that it has attracted much of the attention of Europeans ever since it was visited in the 13th century by Marco Paulo the Venetian traveller. Of such a country it would be unpardonable not to give some account in a work of this nature; but we have not, in truth, much to add to what has been said of China and the Chinese in the *Encyclopædia Britannica*. Since the article CHINA in that work was published, the court of Peking has indeed been visited by an embassy from Great Britain, and the origin of the people, as well as the antiquity of their empire, has been investigated by Sir William Jones with his usual diligence; but from his memoir, published in the second volume of the *Asiatic Researches*, and from Sir George Staunton's account of the embassy, there is not much to be extracted which would be either amusing or instructive to our readers.

We have already observed from Grofier and others, that the Chinese not only lay claim to the highest antiquity, but even contend that their first emperor was the first man. Both these positions are controverted by Sir William Jones, who, though he allows the Chinese empire to be very ancient when compared with the oldest European state, is yet decidedly of opinion that it was not founded at an earlier period than the 12th century before the Christian era; and that the people, so far from being aborigines, are a mixed race of Tartars and Hindoos. He begins his investigation with asking, "Whence came the singular people who long had governed China, before they were conquered by the Tartars? On this problem (says he*) four opinions* *Asiatic Researches*, vol. ii. mem. 25. have been advanced, and all rather peremptorily asserted than supported by argument and evidence. By a few writers it has been urged, that the *Chinese* are an original race, who have dwelled for ages, if not from eternity, in the land which they now possess. By others, and chiefly by the missionaries, it is insisted that they sprung from the same stock with the *Hebrews* and the *Arabs*. A third assertion is that of the *Arabs* themselves, and of M. PAUW, who hold it indubitable, that they were originally *Tartars*, descending in wild clans from the steeps of Imaus: And a fourth, at least as dogmatically pronounced as any of the preceding, is that of the *Brabmans*, who decide, without allowing any appeal from their decision, that the *Chinas* (for so they are named in *Sanscrit*) were Hindoos of the military cast, who, abandoning the privileges of their tribe, rambled in different bodies to the north-east of *Bengal*; and forgetting by degrees the rites and the religion of their ancestors, established separate principalities, which were afterwards united in the plains and valleys which are now possessed by them.

Of these opinions, Sir William having very completely demolished the first three, proceeds to establish the fourth, which he considers as interesting as well as new in Europe. In the *Sanscrit* institutes of civil and religious duties, revealed, as the Hindoos believe, by MENVU the

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the fon of Brahma, we find (says he) the following curious passage: ‘Many families of the military class, having gradually abandoned the ordinances of the *Veda*, and the company of *Brahmans*, lived in a state of degradation; as the people of *Pundraca* and *Odra*, those of *Dravira* and *Camboja*, the *Yavanas* and *Sacas*, the *Paradas* and *Pablavas*, the *CHINAS*, and some other nations.’ A full comment on this text (continues the president) would be superfluous; but since the testimony of the Indian author, who, though not a divine personage, was certainly a very ancient lawyer, moralist, and historian, is direct and positive, disinterested and unsuspected, it would decide the question before us if we could be sure that the word *China* signifies a *Chinese*.” Of this fact Sir William Jones took the very best methods to be satisfied. He consulted a number of Pandits separately, who all assured him that the word *China* has no other signification in *Sanscrit*; that the *Chinas* of *MENU* settled in a fine country to the north-east of *Gaur*, and to the east of *Camarup* and *Napal*; that they had long been, and still are, famed as ingenious artificers; and that they (the Pandits) had themselves seen old Chinese idols, which bore a manifest relation to the primitive religion of India. He then laid before one of the best informed *Pandits* a map of Asia; and when his own country was pointed out to him, the *Pandit* immediately placed his finger on the north-western provinces of China, as the place where he said the *Chinas* of *MENU* first established themselves.

In the opinion of Sir William Jones, this is complete evidence that the Chinese are descended from an Indian race; but he does not believe that the Chinese empire, as we now call it, was formed when the laws of *MENU* were collected; and for his calling this fact in question, he offers reasons, which to us are perfectly satisfactory. By a diligent and accurate comparison of ancient *Sanscrit* writings, he has been able to fix the period of the compilation of those laws at between 1000 and 1500 years before Christ; but by the evidence of Confucius himself, he proves, that if the Chinese empire was formed, it could be only in its cradle in the 12th century before our era. In the second part of the work, intitled *Lün Yü*, Confucius declares, that “although he, like other men, could relate, as mere lessons of morality, the histories of the first and second imperial houses, yet, *for want of evidence*, he could give no certain account of them.” Now, says Sir William, if the Chinese themselves do not pretend that any historical monument existed in the age of Confucius preceding the rise of their third dynasty, about 1100 years before the Christian epoch, we may justly conclude that their empire was then in its infancy, and did not grow to maturity till some ages afterwards. Nay, he is inclined to bring its origin still lower down. “It was not, says he, till the eighth century before the birth of our Saviour, that a small kingdom was erected in the province of *Shen si*, the capital of which stood nearly in the 35th degree of northern latitude, and about five degrees to the west of *Si-gan*. That country and its metropolis were both called *Chin*; and the dominion of its princes was gradually extended to the east and west. The territory of *Chin*, so called by the old Hindoos, by the Persians, and by the Chinese, gave its name to a race of emperors, whose tyranny made their memory so unpopular, that the modern inhabitants of China hold the

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word in abhorrence, and speak of themselves as the people of a milder and more virtuous dynasty: but it is highly probable that the whole nation descended from the *Chinas* of *MENU*, and mixing with the *Tartars*, by whom the plains of *Honan* and the more southern provinces were thinly inhabited, formed by degrees the race of men whom we now see in possession of the noblest empire in Asia.”

In support of this opinion, which the accomplished author offers as the result of long and anxious inquiries, he observes, that the Chinese have no ancient monuments from which their origin can be traced, even by plausible conjecture; that their sciences are wholly *exotic*; that their mechanic arts have nothing in them which any set of men, in a country so highly favoured by nature, might not have discovered and improved; that their philosophy seems yet in so rude a state as hardly to deserve the appellation; and that their popular religion was imported from *India* in an age comparatively modern. He then institutes a comparison between the mythology of the Chinese and that of the Hindoos; of which the result is, that the former people had an *ancient* system of ceremonies and superstitions which has an apparent affinity with some parts of the oldest Indian worship. “They believed in the agency of genii or tutelary spirits, presiding over the stars and the clouds; over lakes and rivers, mountains, valleys, and woods; over certain regions and towns; over all the elements, of which, like the Hindoos, they reckoned five; and particularly over *fire*, the most brilliant of them. To those deities they offered victims on high places. And the following passage from one of their sacred books, says Sir William, is very much in the style of the *Brahmans*: ‘Even they who perform a sacrifice with due reverence, cannot perfectly assure themselves that the divine spirits accept their oblations; and far less can they, who adore the gods with languor and oscitancy, clearly perceive their sacred illapses.’ These (continues the President) are imperfect traces indeed, but they *are* traces of an affinity between the religion of *MENU* and that of the *Chinas*, whom he names among the apostates from it; and besides them, we discover many other very singular marks of relation between the Chinese and the old Hindoos.

“This relation (he thinks) appears in the remarkable period of 432,000, and the cycle of 60 years; in the predilection for the mystical number *nine*; in many similar fests and great festivals, especially at the solstices and equinoxes; in the obsequies, consisting of rice and fruits offered to the manes of their ancestors; in the dread of dying childless, lest such offerings should be intermitted; and perhaps in their common abhorrence of *red* objects, which the Indians carried so far, that *MENU* himself, where he allows a *Brahman* to trade, if he cannot otherwise support life, absolutely forbids his trading in any sort of *red* cloths, whether linen, or woollen, or made of woven bark. In a word, says Sir William Jones, all the circumstances which have been mentioned seem to prove (as far as such a question admits proof), that the Chinese and Hindoos were originally the same people; but having been separated near 4000 years, they have retained few strong features of their ancient consanguinity, especially as the Hindoos have preserved their old language and ritual, while the Chinese very soon lost both; and the Hindoos have

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constantly intermarried among themselves, while the Chinese, by a mixture of Tartarian blood from the time of their first establishment, have at length formed a race distinct in appearance both from Indians and Tartars."

Sir George Staunton, who accompanied the Earl of Macartney on his embassy to the Emperor of China, does not indeed directly controvert this reasoning; but overlooking it altogether, gives to the Chinese a much higher antiquity than Sir William Jones is inclined to allow them. Taking it for granted that their *cycle* is their own, and that it is not the offspring of astronomical science, but of repeated observations, he seems to give implicit credit to those annals of the empire which almost every other writer has considered as fabulous.

"Next to the studies which teach the economy of life, the Chinese (says he) value most the history of the events of their own country, which is, to them, the globe; and of the celestial movements which they had an opportunity of observing at the same time." In regard to the former, he tells us, that "from about *three* centuries before the Christian era the transactions of the Chinese empire have been regularly, and without any intervening chasm, recorded both in official documents and by private contemporary writers. Nowhere had history become so much an object of public attention, and nowhere more the occupation of learned individuals. Every considerable town throughout the empire was a kind of university, in which degrees were conferred on the proficient in the history and government of the state. Historical works were multiplied throughout. The accounts of *recent* events were exposed to the correction of the witnesses of the facts, and compilations of former transactions to the criticisms of rival writers." In regard to the latter, the movements of the heavenly bodies, he thinks that in no country are there stronger inducements or better opportunities to watch them than in China; and hence he infers, that the cycle of sixty years is of Chinese formation. "In a climate (says he) favourable to astronomy, the balance of hours beyond the number of days during which the sun appeared to return opposite to, and to obscure, or to mix among the same fixed stars, might be ascertained in a short time; and occasioned the addition of a day to every fourth year, in order to maintain regularity in the computation of time, in regard to the return of the seasons; but many ages must have past before a period could have been discovered, in which the unequal returns of the sun and moon were so accurately adjusted, that at its termination the new and full moons should return, not only to the same day, but within an hour and a half of the time they had happened, when the period commenced. The knowledge of such a period or cycle could be obtained only by a multiplicity of careful and accurate observations. Many revolutions of those great luminaries must have been completed, and numberless conjunctions have past over, before their returns could be ascertained to happen in the same day, at the end of nineteen years. The small difference of time between the returning periods of this cycle, was partly lessened by the intervention of another of 60 years; or of 720 revolutions of the moon, which, with the settled intercalation of 22 lunations, were at first supposed to bring a perfect coincidence of the relative positions of the sun and moon: but even according to this period, every new year was made constantly to recede, in a very small degree, which

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the Chinese corrected afterwards from time to time. This cycle answered a double purpose, one as an era for chronological reckoning, and the other as a regulating period for a luni-solar year. Each year of the cycle is distinguished by the union of two characters, taken from such an arrangement of an unequal number of words placed in opposite columns, that the same two characters cannot be found again together for sixty years. The first column contains a series of ten words, the other twelve; which last are, in fact, the same that denote the twelve hours or divisions of the day, each being double the European hour. The first word or character of the first series or column of ten words, joined to the first word of the second series or column of twelve, marks the first year of the cycle; and so on until the first series is exhausted, when the eleventh word of the second series, combined with the first of the first series, marks the eleventh year of the cycle; and the twelfth or last of the second series, joined with the second of the first series, serves for denoting the twelfth year. The third of the first series becomes united in regular progression with the first of the second series, to mark the thirteenth year; and proceeding by this rule, the first character in the first and in the second series cannot come again together for sixty years, or until the first year of the second cycle. The Christian year 1797 answers to the 54th year of the 60th Chinese cycle, which ascertains its commencement to have been 2277 years before the birth of Christ; unless it be supposed that the official records and public annals of the empire, which bear testimony to it, should all be falsified, and that the cycle when first established should have been antedated; which is indeed as little probable as that the period, for example, of the Olympiads should be asserted to have commenced many ages prior to the first Olympic games."

This is a very positive decision against the opinion of a man whose talents and knowledge of oriental learning were such as to give to his opinions on such subjects the greatest weight. If the statements and reasonings of Sir George Staunton be accurate, the Chinese empire must have subsisted at least 3000 years before the Christian era; for he says expressly, that *many ages* must have elapsed before the commencement of that cycle, which, according to him, commenced 2277 years before the birth of Christ. But surely Confucius was as well acquainted with the ancient annals of his own country, and the credibility which is due to them, as any man of the present age, whether Chinese or European; and we have seen, that he considered none of them as authentic which relate events previous to the 11th century before our era. Even this is by much too early a period at which to rely upon them with implicit confidence, if it be true, as Sir George informs us, that the transactions of the empire have been regularly recorded only from about *three* centuries before the birth of Christ. With respect to the cycle, there is every probability that it was derived from India, where we know that astronomy has been cultivated as a science from time immemorial, and where, we have shewn in another place, that the commencement of the cycle was actually antedated (see PHILOSOPHY, n° 9. *Encycl.*) We have therefore no hesitation in preferring Sir William Jones's opinion of the origin of the Chinese empire to Sir George Staunton's; not merely because we believe

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China. the former of these gentlemen to have been more conversant than the latter with Chinese literature, but because we think his reasoning more consistent with itself, and his conclusion more consonant to that outline of chronology, which, as he observes, has been so correctly traced for the last 2000 years, that we must be hardy sceptics to call it in question.

There is another point very nearly related indeed to this, about which these two learned men likewise differ. Sir George Staunton informs us, that "no accounts of a general deluge are mentioned in Chinese history." Sir William Jones, on the other hand, in the discourse already quoted, says, "I may assure you, after full inquiry and consideration, that the Chinese, like the Hindoos, believe this earth to have been wholly covered with water, which, in works of undisputed authenticity, they describe as *flowing abundantly, then subsiding, and separating the higher from the lower age of mankind.*" To which of these authors shall we give credit? The high antiquity which Sir George Staunton assigns to the Chinese empire, rendered it necessary for the persons from whom he drew his information to get quit by any means of an universal deluge. The system of Sir William Jones left him at liberty to admit or reject that event according to evidence; and in addition to the authentic records to which he appeals, he quotes a mythological fable of the Chinese, and another of the Hindoos, which, though he lays not upon them any great stress, appear to us, when compared together, not only to corroborate his opinion respecting the descent of the Chinese, but likewise to shew that both they and the Hindoos have preserved a traditionary account of the deluge very similar to that which is given by Moses. The Chinese fable is this: "The mother of FO-HI was the *daughter of Heaven*, surnamed *Flower-loving*; and as the nymph was walking alone on the brink of a river with a similar name, she found herself on a sudden encircled with a *rainbow*; soon after which she became pregnant, and at the end of twelve years was delivered of a son, radiant as herself, who, among other titles, had that of *Sui*, or *the Star of the Year.*" In the mythological system of the Hindoos, "the nymph ROHINI, who presides over the fourth lunar mansion, was the favourite mistress of SOMA or the Moon, among whose numerous epithets we find *Cumudanáyaca*, or delighting in a species of *water-flower* that blossoms at night. The offspring of ROHINI and SOMA was BUDA, regent of a planet; and he married ILA, whose father was preserved in a *MIRACULOUS ARK* from an universal deluge." The learned president shews, that, according to the Brahmans, the Chinese descended from BUDA; and he mentions a divine personage connected with the Chinese account of the birth of FO-HI, whose name was NIU-VA. But if all these circumstances be laid together, it will appear, we think, pretty evident, that the two ancient nations have preserved the same tradition of an universal deluge, and that the Chinese RAINBOW and NIU-VA, with the Indian ARK, point to the flood of NOAH.

To Sir William Jones's derivation of the Chinese from the Hindoos, the state of their written language may occur as an objection; for since it is certain that alphabetical characters were in use among the Hindoos before the period at which he places the emigration of the *Chinas*, how, it may be asked, came these people to

drop the mode of writing practised by their ancestors, and to adopt another so very inconvenient as that which the Chinese have used from the foundation of their empire? The force of this objection, however, will vanish, when it is remembered that the *Chinas* were of the military cast; that they had gradually abandoned the ordinances of the Veda, and were in consequence degraded; and that they rambled from their native country in small bodies. We do not know that the military cast among the Hindoos was ever much devoted to letters; there is the greatest reason to believe that a degraded cast would neglect them; and it is certain that small bodies of men, wandering in deserts, would have their time and their attention completely occupied in providing for the day that was passing over them. That the *Chinas* should have forgotten the alphabetical characters of the Hindoos, is therefore so far from being an objection to Sir William Jones's account of their descent from that people, that it is the natural consequence of the manner in which he says they rambled from Hindostan to the northern provinces of what now constitutes the Chinese empire.

Of the origin of the characters which are used by this singular people, the illustrious president of the Asiatic Society gives the following account from a Chinese writer named LI YANG PING. "The earliest of them were nothing more than the outlines of visible objects, earthly and celestial; but as things merely intellectual could not be expressed by those figures, the grammarians of *China* contrived to represent the various operations of the mind by metaphors drawn from the productions of nature. Thus the idea of roughness and of rotundity, of motion and rest, were conveyed to the eye by signs representing a mountain, the sky, a river, and the earth. The figures of the sun, the moon, and the stars, differently combined, stood for smoothness and splendour, for any thing artfully wrought, or woven with delicate workmanship. Extension, growth, increase, and many other qualities, were painted in characters taken from the clouds, from the firmament, and from the vegetable part of the creation. The different ways of moving, agility and slowness, idleness and diligence, were expressed by various insects, birds, fishes, and quadrupeds. In this manner passions and sentiments were traced by the pencil, and ideas not subject to any sense were exhibited to the sight; until by degrees new combinations were invented, new expressions added, the characters deviated imperceptibly from their primitive shape, and the Chinese language became not only clear and forcible, but rich and elegant in the highest degree*."

Of this language, both as it is spoken and written, Sir George Staunton has given an account so clear and scientific, that it will undoubtedly place him high among the most eminent philologists of the 18th century. As there is nothing relating to the Chinese more wonderful than their language, which is very little understood in Europe, we shall lay before our readers a pretty copious abstract of what he says on the subject, referring them for further information to his account of Lord Macartney's Embassy to China.

"In the Chinese tongue (says Sir George) the sounds of several letters in most alphabets are utterly unknown, and the organs of a native advanced in life cannot pronounce them. In endeavouring to utter the

* *Asiatic Researches*, vol. ii. Memoir 13.

China. sounds of B, D, R, and X, for instance, he substitutes some other sounds to which the same organ has been accustomed; L for R, and, as we have reason to think from some expressions of Sir William Jones's, F for B. The nice distinctions between the tones and accents of words nearly resembling each other in sound, but varying much in sense, require a nicety of ear to distinguish, and of vocal powers to render them exactly. Synonymous words are therefore frequently introduced in Chinese dialogue to prevent any doubt about the intended sense; and if in an intricate discussion any uncertainty should still remain as to the meaning of a particular expression, recourse is had to the ultimate criterion of tracing with the finger in the air, or otherwise, the form of the character, and thus ascertaining at once which was meant to be expressed. In a Chinese sentence there is no marked distinction of substantives, adjectives, or verbs; nor any accordance of gender, number, and case. A very few particles denote the past, the present, and the future; nor are those auxiliaries employed when the intended time may be otherwise inferred with certainty. A Chinese who means to declare his intention of departing to-morrow, never says that he *will* depart to-morrow; because the expression of the morrow is sufficient to ascertain that his departure must be future. The plural number is marked by the addition of a word, without which the singular always is implied. Neither the memory nor the organs of speech are burthened with the pronunciation of more sounds to express ideas than are absolutely necessary to mark their difference. The language is entirely monosyllabic. A single syllable always expresses a complete idea. Each syllable may be sounded by an European consonant preceding a vowel, sometimes followed by a liquid. Such an order of words prevents the harshness of succeeding consonants sounding ill together; and renders the language as soft and harmonious as the Italian is felt to be, from the rarity of consonants, and the frequency of its vowel terminations.

"The names or sounds, by which men may be first supposed to have distinguished other animals, when occasion offered to designate them in their absence, were attempts at an imitation of the sounds peculiar to those beings; and still, in Chinese, the name, for example, of a cat, is a pretty near resemblance of its usual cry. It occurred as naturally to endeavour, in speaking, to imitate the voice, if practicable, as it was in writing to sketch a rude figure of the object of description. It is observable, that the radical words of most languages, separated from the servile letters which mark their inflections, according to their conjugations or declensions, are monosyllabic. A part of each radical word is retained in composition to denote the meaning and etymology of the compound, which thus becomes polysyllabic; but the Chinese grammarians, aware of the inconvenience resulting from the length and complication of sounds, confined all their words, however significant of combined ideas, to single sounds; and retained only in writing, some part at least of the form of each character denoting a simple idea, in the compound characters conveying complex ideas."

This is a very plausible, and perhaps the true, account of the monosyllabic form of the Chinese language; but it is proper to state the different account which is given of this peculiarity by Sir William Jones. "It

China. has arisen, according to him, from the singular habits of the people; for though their common tongue be so *musically* accented as to form a kind of recitative, yet it wants those *grammatical* accents without which all human tongues would appear monosyllabic. Thus *Amita*, with an accent on the first syllable, means, in the *Sanscrit* language, *immeasurable*, and the natives of Bengal pronounce it *Omito*; but when the religion of BUDDHA, the son of Mâyá, was carried into *China*, the people of that country, unable to pronounce the name of their new god, called him FOE, the son of MO-YE; and divided his epithet *Amita* into three syllables O-MI-TO, annexing to them certain ideas of their own, and expressing them in writing by three distinct symbols. Hence it is that they have clipped their language into monosyllables, even when the ideas expressed by them, and the written symbols for those ideas, are very complex."

"In the Chinese language Sir George Staunton informs us, that there is a certain order, or settled syntax, in the succession of words in the same sentence; a succession fixed by custom, differently in different languages, but founded on no rule or natural order of ideas, as has been sometimes supposed; for though a sentence consists of several ideas, to be rendered by several words, these ideas all exist and are connected together in the same instant; forming a picture or image, every part of which is conceived at once. The formation of Chinese sentences is often the simplest and most artless possible, and such as may naturally have occurred at the origin of society. To interrogate, for example, is often at least to require the solution of a question, whether the subject of doubt be in a particular way or the contrary; and accordingly a Chinese inquiring about his friends health, will sometimes say, *hou, poo hou?* The literal meaning of which words is, "well, not well?" A simple character repeated stands sometimes for more than one of the objects which singly it denotes, and sometimes for a collective quantity of the same thing. The character of *mo* singly is a tree, repeated is a thicket, and tripled is a forest.

"In Chinese there are scarcely fifteen hundred distinct sounds. In the written language there are at least eighty thousand characters or different forms of letters, which number divided by the first gives nearly fifty senses or characters upon an average to every sound expressed; a disproportion, however, that gives more the appearance than the reality of equivocation and uncertainty to the oral language of the Chinese.

"The characters of the Chinese language were originally traced, in most instances, with a view to express either real images, or the allegorical signs of ideas: a circle, for example, for the sun, and a crescent for the moon. A man was represented by an erect figure, with lines to mark the extremities. It was evident that the difficulty and tediousness of imitation will have occasioned soon a change to traits more simple and more quickly traced. Of the entire figure of a man, little more than the lower extremities only continue to be drawn, by two lines forming an angle with each other. A faint resemblance, in some few instances, still remains of the original forms in the present hieroglyphic characters; and the gradation of their changes is traced in several Chinese books. Not above half a dozen of the present characters consist each of a single line; but most

of them consist of many, and a few of so many as seventy different strokes. The form of those characters has not been so flux as the sound of words, as appears in the instance of almost all the countries bordering on the Chinese Sea or Eastern Asia, where the Chinese written, but not the oral language, is understood; in like manner, as one form of Arabic figures to denote numbers, and one set of notes for music, are uniform and intelligible throughout Europe, notwithstanding the variety of its languages.

“ A certain order or connection is to be perceived in the arrangement of the written characters of the Chinese; as if it had been formed originally upon a system to take place at once, and not grown up, as other languages, by slow and distant intervals. Upwards of two hundred characters, generally consisting each of a few lines or strokes, are made to mark the principal objects of nature, somewhat in the manner of Bishop Wilkin's divisions, in his ingenious book on the subject of universal language, or real character. These may be considered as the genera or roots of language, in which every other word or species, in a systematic sense, is referred to its proper genus. The heart is a genus, of which the representation of a curve line approaches somewhat to the form of the object; and the species referable to it include all the sentiments, passions, and affections, that agitate the human breast. Each species is accompanied by some mark denoting the genus or heart. Under the genus *hand* are arranged most trades and manual exercises. Under the genus *word* every sort of speech, study, writing, understanding, and debate. A horizontal line marks a unit; crossed by another line it stands for ten, as it does in every nation which repeats the units after that number. The five elements, of which the Chinese suppose all bodies in nature to be compounded, form so many genera, each of which comprehends a great number of species under it. As in every compound character or species, the abridged mark of the genus is discernible by a student of that language, in a little time he is enabled to consult the Chinese dictionary, in which the compound characters or species are arranged under their proper genera. The characters of these genera are placed at the beginning of the dictionary, in an order which, like that of the alphabet, is invariable, and soon becomes familiar to the learner. The species under each genus follow each other, according to the number of strokes of which each consists, independently of the one or few which serve to point out the genus. The species wanted is thus soon found out. Its meaning and pronunciation are given through other words in common use; the first of which denotes its signification and the other its sound. When no one common word is found to render exactly the same sound, it is communicated by two words with marks, to inform the inquirer that the consonant of the first word and the vowel of the second joined together form the precise sound wanted.

“ The composition of many of the Chinese characters often displays considerable ingenuity, and serves also to give an insight into the opinions and manners of the people. The character expressive of happiness includes abridged marks of land, the source of their physical, and of children that of their moral, enjoyments. This character, embellished in a variety of ways, is hung up almost in every house. Sometimes written by the

hand of the emperor, it is sent by him as a compliment, which is very highly prized, and such as he was pleased to send to the ambassador.

“ Upon the formation, changes, and allusions of compound characters, the Chinese have published many thousand volumes of philological learning. Nowhere does criticism more abound, or is more strict. The introduction or alteration of a character is a serious undertaking, and seldom fails to meet with opposition. The most ancient writings of the Chinese are still classical amongst them. The language seems in no instance to have been derived from or mixed with any other. The written seems to have followed the oral language soon after the men who spoke it were formed into a regular society. Though it is likely that all hieroglyphical languages were originally founded on the principles of imitation, yet in the gradual progress towards arbitrary forms and sounds, it is probable that every society deviated from the originals in a different manner from the others; and thus for every independent society there arose a separate hieroglyphic language. As soon as a communication took place between any two of them, each would hear names and sounds not common to both; each reciprocally would mark down such names in the sounds of its own characters, bearing, as hieroglyphics, a different sense. In that instance, consequently, those characters cease to be hieroglyphics, and were merely marks of sound. If the foreign sounds could not be expressed but by the use of a part of two hieroglyphics, in the manner mentioned to be used sometimes in Chinese dictionaries, the two marks joined together become in fact a syllable. If a frequent intercourse should take place between communities speaking different languages, the necessity of using hieroglyphics merely as marks of sound would frequently recur. The practice would lead imperceptibly to the discovery that, with a few hieroglyphics, every sound of the foreign language might be expressed; and the hieroglyphics which answered best this purpose, either as to exactness of sound or simplicity of form, would be selected for this particular use; and serving as so many letters, would form in fact together what is called an alphabet. Thus, the passage from hieroglyphic to alphabetic writing may naturally be traced, without the necessity of having recourse to divine instruction, as some learned men have conjectured, on the ground that the art of writing by an alphabet is too refined and artificial for untutored reason.”

“ The Chinese printed character is the same as is used in most manuscripts, and is chiefly formed of straight lines in angular positions, as most letters are in Eastern tongues, especially the Sanscrit; the characters of which, in some instances, admit of additions to their original form, producing a modification of the sense. A running hand is used by the Chinese only on trivial occasions, or for private notes, or for the ease and expedition of the writer; and differs from the other as much as an European manuscript does from print. There are books with alternate columns of both kinds of writing for their mutual explanation to a learner.

“ The principal difficulty in the study of Chinese writings arises from the general exclusion of the auxiliary particles of colloquial language, that fix the relation between indeclinable words, such as are all those of the Chinese language. The judgment must be constantly exercised

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exercised by the student, to supply the absence of such assistance. That judgment must be guided by attention to the manners, customs, laws, and opinions of the Chinese, and to the events and local circumstances of the country, to which the allusions of language perpetually refer. If it in general be true, that a language is difficult to be understood in proportion to the distance of the country where it is spoken, and that of him who endeavours to acquire it, because in that proportion the allusions to which language has continually recourse are less known to the learner, some idea may be conceived of the obstacles which an European may expect to meet in reading Chinese, not only from the remoteness of situation, but from the difference between him and the native of China in all other respects. The Chinese characters are in fact sketches or abridged figures, and a sentence is often a string of metaphors. The different relations of life are not marked by arbitrary sounds, simply conveying the idea of such connection; but the qualities naturally expected to arise out of such relations become frequently the name by which they are respectively known. Kindred, for example, of every degree is thus distinguished with a minuteness unknown in other languages. That of China has distinct characters for every modification known by them of objects in the physical and intellectual world. Abstract terms are no otherwise expressed by the Chinese than by applying to each the name of the most prominent objects to which it might be applied, which is likewise indeed generally the case of other languages. Among the Latins the abstract idea of virtue, for example, was expressed under the name of valour or strength (*virtus*), being the quality most esteemed among them, as filial piety is considered to be in China. The words of an alphabetic language being formed of different combinations of letters or elemental parts, each with a distinct sound and name, whoever knows and combines these together, may read the words without the least knowledge of their meaning; not so hieroglyphic language, in which each character has indeed a sound annexed to it, but which bears no certain relation to the unnamed lines or strokes of which it is composed. Such character is studied and best learned by becoming acquainted with the idea attached to it; and a dictionary of hieroglyphics is less a vocabulary of the terms of one language with the correspondent terms in another, than an encyclopædia containing explanations of the ideas themselves represented by such hieroglyphics. In such sense only can the acquisition of Chinese words be justly said to engross most of the time of men of learning among them. The knowledge of the sciences of the Chinese, however imperfect, and of their most extensive literature, is certainly sufficient to occupy the life of man. Enough, however, of the language is imperceptibly acquired by every native, and may, with diligence, be acquired by foreigners for the ordinary concerns of life; and further improvements must depend on capacity and opportunity."

Next to the singular structure of the oral and written language of the Chinese, there is perhaps nothing in their history more surprising to a native of Europe than the number of the people, and the means by which they contrive to procure subsistence, without foreign trade, in a country so crowded, and at the same time not everywhere of a fertile soil. In the Encyclopædia, the population of this vast empire is stated, from M.

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Grosier, at 200 millions: but great as this is, when compared with the population of every other extensive country, it appears to be far short of the truth. Sir George Staunton has published a statement, taken from one of the public offices in the capital, and given by a great and respectable manderin to Lord Macartney, in which it is shewn that China Proper contains not fewer than 333 millions of inhabitants. As the extent of the country is 1,297,999 square miles, there are of course very near 260 inhabitants to every square mile; and of these miles a very considerable proportion consists of nothing but barren rocks. That this account is accurate there can be little doubt; for the extent of the provinces was ascertained by astronomical observations, as well as by admeasurement; and the number of individuals is regularly taken in each division of a district by a tything-man, or every tenth master of a family. These returns are collected by officers resident so near as to be capable of correcting any gross mistake, and are all lodged in the great register of Pekin.

For this excessive population our author satisfactorily accounts. Celibacy, says he, is rare in China, even in the military profession; the marriages are prolific as well as early, and the influence of the patriarchal system, to be explained afterwards, is such, that a man's children adds to his wealth. It is reckoned a discredit to be without offspring; and they who have none adopt others, who become theirs exclusively. In case of marriage, should a wife prove barren, a second may be espoused in the lifetime of the first. The opulent, as in most parts of the East, are allowed, without reproach, to keep concubines, of whom the children are considered as being those of the legitimate wife, and partake in all the rights of legitimacy. "Accidents sometimes of extraordinary drought, and sometimes of excessive inundations, occasionally produce famine in particular provinces, and famine disease; but there are few drains from moral causes either of emigration or foreign navigation. The number of manufactures, whose occupations are not always favourable to health, whose constant confinement to particular spots, and sometimes in a close or tainted atmosphere, must be injurious, and whose residence in towns exposes them to irregularities, bears but a very small proportion to that of husbandmen in China. In general there seems to be no other bounds to Chinese populousness than those which the necessity of subsistence may put to it. These boundaries are certainly more enlarged than in other countries. The whole surface of the empire is, with trifling exceptions, dedicated to the production of food for man alone. There is no meadow, and very little pasture; nor are fields cultivated in oats, beans, or turnips, for the support of cattle of any kind. Few parks or pleasure grounds are seen, excepting those belonging to the emperor. Little land is taken up for roads, which are few and narrow, the chief communication being by water. There are no commons, or lands suffered to lie waste by the neglect, or the caprice, or for the sport of great proprietors. No arable land lies fallow. The soil, under a hot and fertilizing sun, yields annually, in most instances, double crops, in consequence of adapting the culture to the soil, and of supplying its defects by mixture with other earths, by manure, by irrigation, by careful and judicious industry of every kind. The labour of man is little diverted from that industry

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to minister to the luxuries of the opulent and powerful, or in employments of no real use. Even the soldiers of the Chinese army, except during the short intervals of the guards which they are called to mount, or the exercises, or other occasional services which they perform, are mostly employed in agriculture. The quantity of subsistence is increased also, by converting more species of animals and vegetables to that purpose than is usual in other countries. And even in the preparation of their food the Chinese have economy and management."

The government of China is despotic; and it is a curious spectacle to behold so large a proportion of the whole human race, connected together in one great system of polity, submitting quietly, and through so considerable an extent of country, to one great sovereign; and uniform in their laws, their manners, and their language, but differing essentially in each of these respects from every other portion of mankind: and neither desirous of communicating with nor forming any designs against the rest of the world. To produce such a phenomenon, many causes must be combined; but perhaps the principal are to be found in the patriarchal system already mentioned, in the laws and customs of the empire, and in the belief that the emperor is the vicegerent of heaven, and guided in all his actions by divine inspiration.

The patriarchal system is founded upon that filial piety which the philosophers of China have uniformly represented as the greatest of human virtues. These sages, while they successfully inculcated this duty, have left parental affection to its own natural influence; and hence in China parents are less frequently neglected than infants are exposed. The laws of the empire, to corroborate the disposition to filial obedience, furnish an opportunity for punishing any breach of it, by leaving a man's offspring entirely within his own power: and hence it is, that with the poor, marriage, as we have said, is a measure of prudence; because the children, particularly the sons, are bound to maintain their parents.

A Chinese dwelling is generally surrounded by a wall six or seven feet high. Within this inclosure a whole family, of three generations, with all their respective wives and children, will frequently be found. One small room is made to serve for the individuals of each branch of the family, sleeping in different beds, divided only by mats hanging from the ceiling. One common room is used for eating.

The prevalence of this custom, of retaining the several branches of a family under the same roof, is attended with important effects. It renders the younger temperate and orderly in their conduct under the authority and example of the older; and it enables the whole to subsist, like soldiers in a mess, with more economy and advantage. As the venerable patriarch of each habitation presides over his descendants with the authority of a magistrate; so the different orders of magistrates are, in their different districts and provinces, looked up to with the veneration due from children to their parents, while the emperor is revered as the grand patriarch of the whole empire.

Another thing which contributes much to the permanency of the government and the internal quiet of the empire is, that in China there is less inequality in the fortunes than in the conditions of men. The ancient

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annals of the empire testify, that for a long period of time, the earth, like the other elements of nature, was enjoyed by its inhabitants almost in common. Their country was divided into small equal districts; every district was cultivated conjointly by eight labouring families, which composed each hamlet; and they enjoyed all the profit of their labours, except a certain share of the produce reserved for public expences. It is true, indeed, that after a revolution, deplored in all the Chinese histories, which happened prior to the Christian era, the usurper granted all the lands away to the partners of his victories, leaving to the cultivators of the soil a small pittance only out of the revenue which it yielded. Property in land also became hereditary; but in process of time, the most considerable domains were subdivided into very moderate parcels by the successive distribution of the possessions of every father equally among all his sons; the daughters being always married without dower. It very rarely happened that there was but an only son to enjoy the whole property of his deceased parents; and it could scarcely be increased by collateral succession.

From the operations of all those causes, there was a constant tendency to level wealth; and few could succeed to such an accumulation of it as to render them independent of any efforts of their own for its increase. Besides, wealth alone confers in China but little importance, and no power; nor is property, without office, always perfectly secure. There is no hereditary dignity, which might accompany, and give it pre-eminence and weight. The delegated authority of government often leans more heavily on the unprotected rich than on the poor, who are less objects of temptation. And it is a common remark among the Chinese, that fortunes, either by being parcelled out to many heirs, or by being lost in commercial speculations, gaming, or extravagance, or extorted by oppressive mandarines, seldom continue to be considerable in the individuals of the same family beyond the third generation. To ascend again the ladder of ambition, it is necessary, by long and laborious study, to excel in the learning of the country, which alone qualifies for public employments.

There are properly but three classes of men in China: men of letters, from whom the mandarines are taken; cultivators of the ground; and mechanics, including merchants. In Pekin alone is conferred the highest degree of literature upon those who, in public examinations, are found most able in the sciences of morality and government as taught in the ancient Chinese writers; with which studies the history of their country is intimately blended. Among such graduates all the civil offices in the state are distributed by the emperor; and they compose all the great tribunals of the empire. The candidates for those degrees are such as have succeeded in similar examinations in the principal city of each province. Those who have been chosen in the cities of the second order, or chief town of every district in the province, are the candidates in the provincial capital. They who fail in the first and second classes have still a claim on subordinate offices, proportioned to the class in which they had succeeded. Those examinations are carried on with great solemnity, and apparent fairness. Military rank is likewise given to those who are found upon competition to excel in the military art, and in warlike exercises. This distribution

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of offices contributes greatly to the peace of the empire; for the people cheerfully submit to the authority of those whom they believe to be placed over them by merit alone, and love that constitution which brings within the reach of the meanest subject, who has talents and industry, the highest station next to the supreme.

"The great tribunals are situated, for the sake of convenience, near the southern gate of the imperial palace at Peking. To them accounts of all the transactions of the empire are regularly transmitted. They are councils of reference from the emperor, to whom they report every business of moment, with the motives for the advice which they offer on the occasion. There is a body of doctrine composed from the writings of the earliest ages of the empire, confirmed by subsequent lawgivers and sovereigns, and transmitted from age to age with increasing veneration, which serves as rules to guide the judgment of those tribunals. This doctrine seems, indeed, founded on the broadest basis of universal justice, and on the purest principles of humanity.

"His imperial majesty generally conforms to the suggestions of those tribunals. One tribunal is directed to consider the qualifications of the different mandarines for different offices, and to propose their removal when found incapable or unjust. One has for object the preservation of the manners or morals of the empire, called by Europeans *the tribunal of ceremonies*, which it regulates on the maxim, that exterior forms contribute not a little to prevent the breach of moral rules. The most arduous and critical is the tribunal of censors; taking into its consideration the effect of subsisting laws, the conduct of the other tribunals, of the princes and great officers of state, and even of the emperor himself. There are several subordinate tribunals; such as those of mathematics, of medicine, of public works, of literature and history. The whole is a regular and consistent system, established at a very early period, continued with little alterations through every dynasty, and revived after any interruption from the caprice or passions of particular princes. Whatever deviation has been made by the present family on the throne, arises from the admission of as many Tartars as Chinese into every tribunal." The opinions of the former are supposed always to preponderate; and many of them are indeed men of considerable talents and strength of mind, as well as polished manners. They are, however, in general, fitter for military than civil offices. The hardy education, the rough manners, the active spirit, the wandering disposition, the loose principles, and the irregular conduct, of the Tartar, fit him better for the profession, practice, and pursuits of war, than the calm, regulated, and domestic habits of the Chinese. Warriors seem naturally the offspring of Tartary, as literati are of China; and accordingly, the principal military commands are conferred on natives of the former country, as, with many exceptions indeed, the chief civil offices are on those of the latter.

A military mandarin, who was much with Lord Macartney, and was himself a distinguished officer, asserted that, "including Tartars, the total of the army in the pay of China amounted to 1,000,000 infantry and 800,000 cavalry. From the observations made by the embassy in the course of their travels through the empire, of the garrisons in the cities of the several orders, and of the military posts at small distances from each

other, there appeared nothing unlikely in the calculation of the infantry; but they met few cavalry. If the number mentioned really do exist, a great proportion of them must have been in Tartary, or on some service distant from the route of the embassy.

"Of the troops, especially cavalry, a vast number are Tartars, who have a higher pay than their Chinese fellow-soldiers. The principal officers of confidence in the army are Tartars also. None of either nation are received into the service but such as are healthy, strong, and fightly. The pay and allowances of a Chinese horseman are three Chinese ounces, heavier than European ounces, and three-tenths of an ounce, of silver, and fifteen measures or rations (the weight not mentioned) of rice every lunar month. A Tartar horseman, seven similar ounces of silver, and 20 measures of rice for the same period. A Chinese foot soldier has one ounce and six-tenths of an ounce of silver, and ten measures of rice; and a Tartar of the same description has two ounces of silver and ten measures of rice every lunar month. The Emperor furnishes the arms, accoutrements, and the upper garment, to all the soldiers. Beside their ordinary pay and allowances, they also receive donations from the Emperor on particular occasions; as when they marry, and when they have male children born. On the death of their parents they obtain 'a gift of consolation;' as do their families when the soldiers themselves die.

"The public revenues of China Proper are said to be little less than 200,000,000 of ounces of silver, which may be equal to about 66,000,000 of pounds sterling; or about three times those of France before the late subversion. From the produce of the taxes all the civil and military expences, and the incidental and extraordinary charges, are first paid upon the spot out of the treasuries of the respective provinces where such expences are incurred; and the remainder is remitted to the Imperial treasury at Peking. This surplus amounted in the year 1792 to the sum of 36,614,328 ounces of silver, or 12,204,776 pounds sterling, according to an account taken in round numbers. In case of insurrections, or other occurrences requiring extraordinary expences, they are generally levied by additional taxes on the provinces adjacent to the scene of action, or connected with the occasion of the expence.

"In the administration of the vast revenue of the state, the opportunities of committing abuses are not often neglected; as may be inferred from the frequent confiscation to the Emperor in consequence of such transgressions. It is indeed affirmed, that much corruption and oppression prevail in most of the public departments, by which considerable fortunes are acquired, notwithstanding the modicity of the public salaries."

With such a standing army and so vast a revenue, it will no longer appear wonderful that one man should govern with despotic sway even the immense multitude of people who inhabit the empire of China, especially trained up as those people are in habits of filial submission to their superiors. But there are some circumstances in the system of Chinese policy, not yet mentioned, which contribute perhaps more than even these habits and that power to preserve the stability of the government. The Emperor reserves to himself alone the right of relieving the wants of the poor, produced by famine or any other unforeseen calamity. On such occasions

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China. he always comes forward. He orders the public granaries to be opened; remits the taxes to those who are visited with misfortune; affords assistance to enable them to retrieve their affairs; and appears to his subjects as standing almost in the place of Providence in their favour. He is perfectly aware by how much a stronger chain he thus maintains his absolute dominion, than the mere dread of punishment would afford. The emperor, to whom the British embassy was sent, shewed himself so jealous of retaining the exclusive privilege of benevolence to his subjects, that he not only rejected, but was offended at, a proposal once made to him by some considerable merchants, to contribute towards the relief of a suffering province; whilst he scrupled not, at the same time, to accept the donation of a rich widow towards the expences of a war in which he was engaged.

This veneration, excited towards the emperor by his apparent benevolence, is increased by an opinion zealously instilled into the people, that he has the faculty of predicting future events of the greatest importance. The Chinese, given up to the dotages of judicial astrology, are firmly persuaded that eclipses of the sun and moon have a powerful influence on the operations of nature and the transactions of mankind; and the periods of their occurrence become, of course, objects of attention and solicitude. The government of the country, ever anxious to establish its authority in the general opinion of its superior wisdom and constant care for the welfare of the people, employs the European missionaries at Pekin (for it is doubtful if any one of the natives has so much science) to calculate eclipses, and then announces them to the people with that solemnity which is fitted to ensure veneration for the superintending power whence such knowledge is immediately derived to them. Eclipses of the sun, in particular, are considered as omenous of some general calamity; and as great pains are taken to inspire them with a belief that their prosperity is owing to the wisdom and virtues of their sovereign, so they are tempted to attribute to some deficiency on his part whatever they think portentous. To this prejudice the emperor finds it prudent to accommodate his conduct. He never ventures on any undertaking of importance at the approach of a solar eclipse, but affects to withdraw himself from the presence of his courtiers, to examine strictly into his late administration of the empire, in order to correct any error, for the commission of which the eclipse may have been an admonition. On these occasions he invites his subjects to give him freely their advice: but it is plain that advice must be offered with great deference to a being for whose admonition the motions of the sun and moon are believed to be regulated; and while such notions are implicitly admitted, the person of the Chinese emperor, as well as his authority, must be looked upon by his subjects as something more than human.

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This is in fact the case. He is not only approached in person with testimonies of the utmost respect, but is adored when absent with all the rites and ceremonies which are used by the Chinese in the worship of their divinities. On his birth-day, at the new and full moon, and probably on other festivals, all the mandarines resident in the neighbourhood of any of his numerous palaces assemble about noon, and repairing to the palace, solemnly prostrate themselves nine times before the throne, their foreheads striking the floor each time; whilst incense is burning on tripods on each side of it, and offerings are made, on an altar before it, of tea and fruits to the spirit of the absent emperor. Over the throne are seen the Chinese characters of glory and perfection; and the name of the Deity is given to the emperor, who is considered by his votaries as possessing in some sense the attribute of ubiquity. Mr Barrow, one of the gentlemen of the embassy, was present at *Tuen-min-yuen*, one of the imperial palaces, when these idolatrous rites of adoration were performed; and he was assured that they took place on that day in all parts of the empire, the prostraters being everywhere attentive to turn their faces towards the capital.

That he who claims adoration in his absence does not appear on his birth-day to receive the compliments of his subjects, will not surprize the reader. The manner in which that festival is celebrated at the palace, where the emperor happens to be resident, is thus described by Sir George Staunton, who witnessed this more than august ceremony at the palace of *Zhe-hai* in Tartary. "The princes, tributaries, ambassadors, great officers of state, and principal mandarines, were assembled in a vast hall; and upon particular notice, were introduced into an inner building, bearing, at least, the semblance of a temple. It was chiefly furnished with great instruments of music, among which were sets of cylindrical bells, suspended in a line from ornamented frames of wood, and gradually diminishing in size from one extremity to the other, and also triangular pieces of metal arranged in the same order as the bells. To the sound of these instruments a slow and solemn hymn was sung by eunuchs, who had such a command of their voices as to resemble the effect of the musical glasses at a distance. The performers were directed, in gliding from one tone to another, by the striking of a shrill and sonorous cymbal; and the judges of music among the gentlemen of the embassy were much pleased with their execution. The whole had indeed a grand effect. During the performance, and at particular signals, nine times repeated, all the persons prostrated themselves nine times, except the ambassador and his suit, who made a profound obeisance (A). But he whom it was meant to honour, continued, as if it were in imitation of the Deity, invisible the whole time."

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(A) The Chinese court, which considers all other sovereigns as subordinate to their own, exacts from foreign ministers, as well as from natives of the empire, nine prostrations upon their first introduction to the emperor. This demand was made, in the last century, of the Dutch, who instantly complied with it in hopes of obtaining in return some lucrative advantages; and the consequence was, that their ambassador was treated with neglect, and dismissed without promise of the smallest favour. It was likewise made of a Russian ambassador in the present century; but he would not comply with it, until a regular agreement was made for its return, on a like occasion, to his own sovereign. Lord Macartney, who was repeatedly urged to go through the same abject ceremony, displayed such firmness and address, that after much evasion it was at last announced to him, that his imperial majesty would be satisfied with the same form of respectful obedience that the English are in the habit of paying to their own sovereign; and upon these terms his lordship was introduced and graciously received.

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the minds of men by this apparent worship of a fellow-mortal might not be too quickly effaced, all scenes of sport and gaiety were postponed to the next day, when a variety of entertainments was exhibited in the presence of the emperor, furrounded by his court and tributary princes.

Notwithstanding the general veneration of the Chinese for the person and government of their emperor, the mandarines asserted that a sect had for ages subsisted in the country, whose chief principles were founded on an antipathy to monarchy; and who nourished hopes of at last subverting it. Their meetings were held in the utmost secrecy, and no man avowed any knowledge of them; but a sort of inquisition was said to be established in order to find them out, and they who were suspected of such sentiments were cut off, or hunted out of society. Should the French declaration of the rights of man, which, through the zeal of its authors, has been translated into one of the languages of India, find its way into China (of which the court is said to be much afraid), it would indeed be a powerful engine in the hands of this secret sect to sap the foundations of the ancient government. The minds of many of the Chinese are far from satisfied with their condition, which lays both their persons and their fortunes at the mercy of the mandarines. No private man in China is exempted from corporal punishment, which may be instantly inflicted on him at the nod of a magistrate; and when he has occasion to speak to a great mandarine, he is obliged, by the police of the country, to throw himself on his knees, and in that posture to communicate his business. The mandarine himself, on the other hand, lies under the hardship of being frequently responsible for events which he could not controul. Upon the general principle that it is his duty to watch over the morals of the people, he is in many cases considered as a criminal for not preventing crimes which he had not been able to prevent. The mandarines are thus aware of not being guaranteed by good conduct against disgrace; and feeling the chagrin of insecurity, many of them must doubtless be ripe for a revolt. Fear may keep them quiet during the reign of a sovereign possessed of abilities and vigilance; but the maxims which regulate the imperial succession are such, that a firm confederacy could hardly fail at the death of an emperor to introduce great changes into the constitution. The throne of China is neither hereditary nor elective. The choice of a successor is left entirely to the reigning prince, who may exclude, as has been instanced, even his own offspring and family. To prevent commotions and fraud, it is no uncommon practice for the emperor, during his lifetime, to declare his successor; for when his succession is settled by a written testament, the throne is not always filled by him for whom it was destined. The father of the emperor to whom the British embassy was sent, is said to have obtained possession of the throne by suddenly entering the palace in the last moments of his predecessor, and substituting his own name in a testament intended for the exaltation of another.

To what has been said in the Encyclopædia of the religion of the Chinese, we have here very little to add. Various deities are worshipped in the empire by very different rites and ceremonies; but there is in China no state religion. None is paid, preferred, or encouraged by it. The emperor is of one faith; many of the man-

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darines of another; and the majority of the common people of a third, which is that of Fo. The men of letters venerate rather than adore Confucius; and meet to honour and celebrate his memory in halls of a simple but neat construction. The numerous and lower classes of the people are less able than inclined to contribute much towards the erection of large and costly edifices for public worship: their attention is almost wholly engaged by their household gods; for every house has its altar and its deities.

“No people are, in fact, more superstitious than the common Chinese. Beside the habitual offices of devotion on the part of the priests and females, the temples are particularly frequented by the disciples of Fo previously to any undertaken of importance; whether to marry, or go a journey, or conclude a bargain, or change situation, or for any other material event in life, it is necessary first to consult the superintendent deity. This is performed by various methods. Some place a parcel of consecrated sticks, differently marked and numbered, which the consultant, kneeling before the altar, shakes in a hollow bamboo, until one of them falls on the ground; its mark is examined, and referred to a correspondent mark in a book which the priest holds open, and sometimes even it is written upon a sheet of paper pasted upon the inside of the temple. Polygonal pieces of wood are by others thrown into the air. Each side has its particular mark; the side that is uppermost when fallen on the floor is in like manner referred to its correspondent mark in the book or sheet of fate. If the first throw be favourable, the person who made it prostrates himself in gratitude, and undertakes afterwards with confidence the business in agitation. But if the throw should be adverse, he tries a second time, and the third throw determines, at any rate, the question. In other respects, the people of the present day seem to pay little attention to their priests. The temples are, however, always open for such as choose to consult the decrees of heaven. They return thanks when the oracle proves propitious to their wishes. Yet they oftener cast lots to know the issue of a projected enterprise than supplicate for its being favourable; and their worship consists more in thanksgiving than in prayer.

“The Chinese are seldom said to carry the objects to be obtained by their devotion beyond the benefits of this life. Yet the religion of Fo professes the doctrine of the transmigration of souls, and promises happiness to the people on conditions, which were no doubt originally intended to consist in the performance of moral duties; but in lieu of which are too frequently substituted those of contributions towards the erection or repair of temples, the maintenance of priests, and a strict attention to particular observances. The neglect of these is announced as punishable by the souls of the defaulters passing into the bodies of the meanest animals, in whom the sufferings are to be proportioned to the transgressions committed in the human form.”

Though the Chinese artists are very ingenious as mere workmen, there is hardly any thing which deserves the name of science in the whole empire. So little is the study of mathematics cultivated, that there are few shopkeepers in China who can perform the ordinary operations of arithmetic; but cast up their accounts by means of an instrument called *swanpan* (See

SWAN-

China. SWANPAN, *Encycl.*). Though the composition of gunpowder was certainly known in China much earlier than in Europe, and though the Chinese had employed it from the beginning in blasting rocks, and in making a vast variety of fire-works; yet Sir George Staunton seems convinced, that they never thought of the invention of guns till they were taught by the Europeans to introduce them into their armies.

The state of physic in this vast country is extremely low, being nowhere taught in public schools or colleges. "A young man who wishes to become a physician, has no other way of acquiring medical knowledge than by engaging himself to some practitioner as an apprentice. He has thus the opportunity of seeing his master's practice, of visiting his patients with him, and of learning such parts of his knowledge and secrets as the other chooses to communicate to him. The emoluments of the profession seldom exceed the skill of the practitioner. As many copper coin as scarcely are equal to sixpence sterling is said to be the usual fee among the people; and perhaps quadruple among the mandarines. Medicine is not divided in China into distinct branches as in most parts of Europe. The same person acts as physician, surgeon, and apothecary. The surgical part of the profession is still more backward than the others. Amputation, in cases of compound fracture and gangrene, is utterly unknown; and death is the speedy consequence of such accidents. The Chinese method of inoculation, which was introduced into the empire about the beginning of the tenth century of our era, is as follows: When the disease breaks out in any district, the physicians of the place carefully collect a quantity of ripe matter from pustules of the proper sort; which being dried and pulverised, is closely shut up in a porcelain jar, so as to exclude from it the atmospheric air; and in this manner it will retain its properties for many years. When the patient has been duly prepared by medicines, generally of an aperient kind, and strictly dieted for a short time, a lucky day is chosen to sprinkle a little of the variolus powder upon a small piece of fine cotton wool, and to insert it into the nostrils of the patient.

"No male physician is allowed to attend a pregnant woman, and still less to practise midwifery; in the delicacy of which both sexes seem to agree in China. There are books written on that art for the use of female practitioners, with drawings of the state and position of the infant at different periods of gestation; together with a variety of directions and prescriptions for every supposed case that may take place: the whole mixed with a number of superstitious observances.

Many practitioners of physic take the advantage, as elsewhere, of the obscurity in which that art is involved, and of the ignorance and credulity of the people, to gain money by the sale of nostrums and secrets of their own. They distribute hand bills, setting forth the efficacy of their medicines, with attested cures annexed to them. And there is one sect which boldly arrogates to itself the possession of a medical secret *not to die!* To those who had all the enjoyments of this life, there remained unaccomplished no other wish than that of remaining for ever in it. And accordingly several sovereigns of China have been known to cherish the idea of the possibility of such a medicine. They had put themselves, in full health, under the care of

those religious empirics, and took large draughts of the boasted beverage of immortality. The composition did not consist of merely harmless ingredients; but probably of such extracts and proportions of the poppy, and of other substances and liquors, as occasioning a temporary exaltation of the imagination, passed for an indication of its vivifying effects. Thus encouraged, they had recourse to frequent repetitions of the dose, which brought on quickly languor and debility of spirits: and the deluded patients often became victims to deceit and folly in the flower of their age.

"There are in China no professors of the sciences connected with medicine. The human body is never, unless privately, dissected there. Books, indeed, with drawings of its internal structure are sometimes published; but these are extremely imperfect, and consulted, perhaps, oftener to find out the name of the spirit under whose protection each particular part is placed, than for observing its form and situation.

"It is a matter of doubt, whether natural history, natural philosophy, or chemistry, be, as sciences, much more improved than anatomy in China. There are several treatises, indeed, on particular subjects in each. The Chinese likewise possess a very voluminous Encyclopædia, containing many facts and observations relative to them; but from the few researches which the gentlemen of the embassy had leisure or opportunity to make during their short visit to the country, they perceived no traces of any general system or doctrine by which separate facts or observations were connected and compared, or the common properties of bodies ascertained by experiment; or where kindred arts were conducted on similar views, or rules framed, or deductions drawn from analogy, or principles laid down to constitute a science."

Of all people the Chinese are perhaps the most eager in their curiosity about foreigners coming among them, and the most indifferent about the countries of such foreigners. They have been always in the habit of confining their ideas to their own country, emphatically styled *the middle kingdom*. No Chinese ever thinks of quitting it, except a few of desperate fortunes residing near the sea-coast, or sea-faring men, who form a class, in a great measure, apart from society. Even foreign commodities consumed in China remind them only of Canton, whence they received them, as if produced in it; and these commodities they consider, perhaps properly, as of no real benefit to the empire. Regions out of Asia are scarcely mentioned in their books, or noticed in their distorted maps; and the great body of the people would be little gratified with accounts of such regions, which did not contain tales of wonders not performed at home, or of powers exerted beyond the ordinary boundaries of nature.

CHINESE PUMP. See PUMP in this Supplement.

CHINESE Weights are so very different in many respects from those in use elsewhere, that it will at least gratify the curiosity of our readers to take some notice of them in this Work. Of these weights Charles Coquebert has presented a specimen to the Philomathematical Society in Paris. They are made of copper, and bear a great resemblance in form to the body of a violin. Like that instrument, they are rounded off at the extremities, and indented on the sides to admit the fingers. The faces are flat and parallel, and have Chinese characters

Chowdry a thing made of wood and covered with leather of sundry colors, some with white, some redde, some yellow. It is called a chapiney, which they wear under their shoes. Many of them are curiously painted; some also of them I have seen fairly gilt; so uncomely a thing, in my opinion, that it is pity this foolish custom is not cleane banished and exterminated out of the citie. *There are many of these chapineys of a great height, even half a yard high, which maketh many of their women that are very short seeme much taller than the tallest women we have in England.* Also I have heard it observed among them, that by how much the nobler a woman is, by so much the higher are her *chapineys*. All their gentlewomen, and most of their wives and widows that are of any wealth, are assisted eyther by men or women when they walke abroad, to the end they may not fall. They are borne up most commonly by the left arme, otherwise they might quickly take a fall."

CHOWDRY, in Bengal, the possessor of several *Talooks*. It is also used as synonymous with *Talookdar*, anciently a collector. See **TALOOK** in this Supplement.

CHRISOM was not, as is said in the *Encyclopædia*, a face-cloth or piece of linen laid over the child's head when it was baptized; but it was a white vesture or garment, which, immediately after it was baptized, the priest put upon it, saying, "Take this white vesture as a token of the innocency, which, by God's grace in this holy sacrament of baptism, is given unto thee, and for a sign whereby thou art admonished, so long as thou livest, to give thyself to innocence of living, that after this transitory life thou mayest be partaker of life everlasting. Amen."

As soon as the priest had pronounced these words, he anointed the infant upon the head, saying, "Almighty God, the Father of our Lord Jesus Christ, who hath regenerated thee by water and the Holy Ghost, and hath given unto thee the remission of all thy sins; he vouchsafe to anoint thee with the unction of his Holy Spirit, and bring thee to the inheritance of everlasting life. Amen."

It was from this anointing or *chrism* that the white garment got the name of *chrifom*, which, after being worn a few days, was offered to the priest to be kept in the church or vestry, in order to be produced as evidence against the person whose *chrifom* it was, should he afterwards deny the faith in which he had been baptized. These ceremonies were retained, for some time after the reformation, in the church of England, which ordered the mother of the child (if the child was then alive) to offer, when she was churched, the *chrifom* and other accustomed offerings. If the child died before its mother was churched, the *chrifom* was not given to the priest, but employed as a shroud, in which the body was buried; and hence it is that *chrifoms* are now enumerated, most absurdly indeed, in the weekly bills of mortality. We say absurdly; because children who die unbaptized are called *chrifoms*, though the *chrifom*, when it was used, was never put on till baptism. See *Whitby on the Book of Common Prayer, &c.*

CHRONOLOGICAL CHARACTERS are characters by which times are distinguished. Of these some are natural or astronomical; others, artificial or historical. The natural characters are such as depend on the motions of the stars or luminaries, as *eclipses, solstices, equi-*

noxes, the different aspects of the planets, &c. The artificial characters are those that have been invented and established by men; as the *solar cycle, the lunar cycle, &c.* Historical chronological characters are those supported by the testimony of historians, when they fix the dates of certain events to certain periods. *Hutton's Mathematical Dictionary.*

CHRONOSCOPE, a word sometimes used to denote a pendulum or machine to measure time.

CHUCKIAH, in Bengal, the jurisdiction of a *Fogedar*. See **FOGEDAR** in this Supplement.

CHURCH is a word which has many different significations, all sufficiently explained in the *Encyclopædia Britannica*, where there is likewise given a concise history of the Christian church (see **HISTORY**, Sect. ii.), defective, indeed, but perhaps not more so than was to be expected from the limits of the work and the extent of the subject.

Of the constitution of the primitive and apostolical church, no man can have a correct notion who has not taken the trouble to consult the primitive and apostolical writers; for, as we have elsewhere observed, all modern compilers of ecclesiastical history are more or less prejudiced in behalf of the particular church to which they belong, and wrest the language of the original writers so as to make them bear witness to the antiquity of *modes of faith and ecclesiastical polity*, which are not perhaps a hundred years old.

On this account we shall not here attempt to correct what we really think the mistakes of him who compiled the section of ecclesiastical history in the *Encyclopædia*. Mosheim and Sir Peter King, whom he seems to have implicitly followed, were indeed great men; and it would be folly to deny that the *History* of the former, and the *Inquiry* of the latter into the *Constitution of the Primitive Church*, are works of learning and ingenuity; but it is not perhaps too much to say, that both authors wrote under the influence of prejudice. Our readers will discover how closely either the one or the other has adhered to truth, by studying the ecclesiastical writers of the first four centuries. Such a study will make them acquainted with the doctrines, discipline, and worship of the church before it was incorporated with the state; and we know not that kind of knowledge which is of more importance to the divine, however much it may be despised in this age of affected science and real ignorance.

Of the principal churches at present existing, a pretty full account is given in the *Encyclopædia*, either under their different denominations, or under the titles of those tenets by which they are chiefly distinguished; so that from that Work alone a reader may form a tolerably accurate notion of the faith, worship, constitution, and discipline of the church of Rome, the churches of England and Scotland, the Lutheran and Calvinistical churches on the continent of Europe, as well as of the various sects which have arisen in these kingdoms during the course of the last and present centuries. There is, however, one church which boasts of a very high antiquity, and is certainly spread over a larger extent of country than all the other churches that we have mentioned, of which the account given in the *Encyclopædia* is exceedingly defective. Our readers will perceive that the church to which we allude is

Church.
I
The Greek church.

Church.

The Greek CHURCH, which comprehends in its bosom (A) a considerable part of Greece, the Grecian isles, Wallachia, Moldavia, Egypt, Abyssinia, Nubia, Lybia, Arabia, Mesopotamia, Syria, Cilicia, and Palestine, which are all under the jurisdiction of the patriarchs of Constantinople, Alexandria, Antioch, and Jerusalem. If to these we add the whole of the Russian empire in Europe, great part of Siberia in Asia, Astracan, Casan, and Georgia—it will be evident that the Greek church has a wider extent of territory than the Latin, with all the branches which have sprung from it; and that it is with great impropriety that the church of Rome is called by her members the catholic or universal church. That in these widely distant countries the professors of Christianity are agreed in every minute article of belief, it would be rash to assert; but there is certainly such an agreement among them with respect both to faith and to discipline, that they mutually hold communion with each other, and are in fact but one church.

2
The faith of that church.

As the Greek church has no public or established articles, like those of the churches of England and Scotland, we can collect what is its doctrine only from its creeds, from the councils whose decrees it receives (B), from the different offices in its liturgies, and from the catechisms which it authorises to be taught. "The doctrine of the Trinity, and the articles of the Nicene and Athanasian creeds, are received by the Greeks in common with other Christians. In one particular, indeed, they differ from the other churches of Europe, whether Romish or reformed. They believe that the Holy Spirit proceeds from the father only, and not from the Father and the Son; and in defence of this opinion they appeal to ecclesiastical history, the acts of councils, the writings of the fathers, ancient manuscripts, and especially to a copy of the creed of Constantinople, engraven on two tables of silver, and hung up in the church of St Peter at Rome by order of Leo III. Of the Nicene or Constantinopolitan creed, therefore, as it is received by them, the eighth article runs in these words, 'I believe in the Holy Ghost, the Lord and Giver of life, who proceedeth from the FATHER, and with the Father and the Son together is worshipped and glorified:'. And the corresponding article of the Athanasian creed is of course, "The Holy Ghost is of the FATHER, neither made, nor created, nor begotten, but proceeding †."

† Dallaway's Constantinople, Ancient and Modern, and King's Rites and Ceremonies, &c.

3
It admits of pictures, but not of graven images.

Though the bishops and clergy of the Greek church abhor the use of images, which they pretend to be one cause of their separation from the see of Rome, they admit into their churches the pictures of saints to instruct, they say, the ignorant, and to animate the devotion of others. This practice they consider as by no means

contrary to the second commandment of the decalogue, which, according to them, prohibits only the worshipping of such idols as the Gentiles believed to be gods; whereas their pictures, being used merely as remembrancers of Christ and the saints, have written on each of them the name of the person whom it is meant to represent. Dr King assures us that the more learned of the Russian clergy would willingly allow no representation whatever of God the Father; and that, during the reign of Peter the Great, the synod not only censured the use of such pictures in churches, but petitioned the emperor that they might be everywhere taken down. Peter, however, though he fully concurred in opinion with the synod, thought this a measure for which the minds of his subjects were not ripe, and dreaded, that if carried into execution it would occasion a general insurrection. Such pictures, therefore, though not more impious than absurd, are still in use; and in many churches, as well ancient as modern, the figure of Daniel's *Ancient of Days*, together with that of *Christ* and a *dove*, are painted in one group to signify the Holy Trinity. Nay, when our author was in St Petersburg, not thirty years ago, there was in the church of St Nicholas the picture of an old man holding a globe, and surrounded with angels, on which GOD THE FATHER was inscribed; and we have not heard that the picture has been since taken down.

In the Greek as well as in the Roman church, the invocation of saints is practised, but they are not invoked in either as deities, but merely as intercessors with the Supreme God, "it being more modest (say the Greeks), as well as more available, to apply to them to intercede with God, than to address ourselves immediately to the Almighty." Plausible as this reasoning may at first sight appear, it ascribes to the saints the divine attribute of ubiquity, and is likewise in direct contradiction to the doctrine of St Paul, who hath taught us, that as "there is one God, so there is but one mediator between God and man, the man Christ Jesus."

4
Invocation of saints.

The Greek church, at the celebration of the Lord's Supper, commemorates the faithful departed, and even prays for the remission of their sins; but she allows not of purgatory, nor pretends to determine dogmatically concerning the state or condition of departed souls. She must, however, believe that no final judgment is passed upon the great body of mankind (c) till the consummation of all things, otherwise such prayers could not be offered without absurdity; and in this part of her doctrine she is certainly countenanced by all the writers of the primitive church, if not by some passages of the sacred scriptures*. The practice of praying for the dead is loudly condemned in every Protestant country, and yet there is no Christian who does not in effect pray

5
Prayers for the dead.

* *Math.* xxv. 19, 20, —31—34. *2 Tim.* i. 18. pray iv. 8.

(A) King's *Rites and Ceremonies of the Greek Church*—Bruce's *Travels to the Source of the Nile*—and Lobo's *Voyage to Abyssinia*.

(B) in the Greek church seven general councils are received, and nine provincial ones. The seven general councils are, 1. The council of Nice, held in the year 325, under Constantine. 2. The first council of Constantinople, held A. D. 381, under Theodosius the Great. 3. The council of Ephesus, A. D. 431, in the reign of Theodosius Minor. 4. The council of Calcedon, A. D. 451, in the reign of Marcian. 5. The second council of Constantinople, A. D. 553, in the reign of Justinian. 6. The third council of Constantinople in Trull, A. D. 680, in the reign of Constantine Pagonatus. 7. The second council of Nice, A. D. 787.

(c) We say the great body of mankind, because she doubtless believes that Enoch, Elias, and those saints who rose with our Saviour, have been already judged, and now enjoy their reward in heaven.

Church.

pray for his departed friends. This may appear a paradox, but it is an obvious and a certain truth; for where is the man who believes in a general judgment, and does not *wish* that his deceased wife, or parent, or child, or friend, "may find mercy of the Lord in that day?" Such a wish is the essence of a prayer; which consists not of the sounds in which our sentiments are clothed, but in the aspirations of a devout heart.

6
Grants no indulgencies.

Supererogation, with its consequent indulgencies and dispensations, which were once so profitable, and afterwards so fatal to the interests of the court of Rome, are utterly disallowed in the Greek church, which likewise lays no claim to the character of infallibility. She is indeed, like some other churches, very inconsistent on this last topic; for whilst she pretends not to an absolute exemption from error, her clergy seem to consider their own particular mode of worship as that which alone is acceptable to God.

7
Predestination.

Predestination is a dogma of the Greek church, and a very prevailing opinion amongst the people of Russia; "and I must do the justice (says Dr King) to those who have written upon it, especially the latest authors of that country, to say that they have treated it, as depending on the attribute of prescience in the divine nature, with a much better kind of logic than that with which such points are generally discussed." As our author has not given us the reasoning of the Russian doctors on this difficult subject, we cannot hazard any opinion of our own on the soundness of their logic; but from the state of science in that vast empire, as it was represented to us by an abler judge than he, we doubt of its being entitled to the praise which he bestows on it. (See RUSSIA, n° 104. *Encycl.*)

8
Seven sacraments.

In the Greek church there are seven *sacraments*; or, as they are there termed, *mysteria*, viz. *baptism*; the *chrism*, or baptismal unction; the *eucharist*; *confession*; *ordination*; *marriage*; and the mystery of *the holy oil*, or *euchelaion*. By the Greeks a mystery is defined to be "a ceremony or act appointed by God, in which God giveth or signifieth his grace; and of the seventh which they celebrate, four are to be received by all Christians, viz. *baptism*, the *baptismal unction*, the *eucharist*, and *confession*. Of these, *baptism* and the *eucharist* are deemed the chief; and of the other three, none, not even the *euchelaion*, is considered as obligatory upon all.

With respect to baptism, we know not that they hold any peculiar opinions. They consider it indeed as so absolutely necessary to salvation, that in cases of extremity, when a priest or deacon cannot be had, it may be administered by a midwife or any other person, and is not to be repeated on any occasion whatever. In this opinion, as well as in the practice founded on it, they are in perfect harmony with the church of Rome, which, as every person knows, has for many ages allowed the validity of lay-baptism in cases of necessity. The Portuguese Jesuits, who in the last century visited Abyssinia in the capacity of missionaries, have maintained that, once every year, all grown people are in that country baptized: but Mr Bruce has shewn, by the most incontrovertible evidence, that this was a mere fiction, invented to throw odium upon what the church of Rome calls the eastern chism, and abhors perhaps more than paganism itself.

9
Daily service of the church,

The daily service of the Greek church is so long and so complicated, that it is impossible for us to give an

adequate account of it without swelling this article far beyond its due proportion. Of this the reader will be convinced, when he is informed that the several books containing the church service for all the days in the year, amount to more than twenty volumes in folio, besides one large volume called *the regulation*, which contains the directions how the rest are to be used.

The four gospels make one volume by themselves; and whenever the gospel is read in any service, the deacon exclaims; "Wisdom, stand up. Let us hear the holy gospel." The priest then saith, "The lesson from the gospel according to St Matthew, St Mark, &c." The deacon says again, "Let us stand." The choir, at the beginning and end of the gospel, always says, "Glory be to thee, O Lord, glory be to thee." From the old testament and the epistles extracts only are used in the service; and when they are to be read, the deacon calls out, "Attend."

The service of this church as it now stands, and was at first drawn up in writing, is calculated for the use of monasteries; and when it was afterwards applied to parochial churches, many of the offices or forms, which were composed for different hours of the day and night, were used as one service, without the slightest alteration being made to avoid repetitions. Something of this kind has taken place in the church of England, where the matins, the litany, and the communion, which were formerly three distinct services, read at different times of the day, are now run into one service; which by those not accustomed to it is therefore deemed long, as well as deformed by needless repetitions.

The service of every day, whether it was a vigil or not, begins in the evening of what we would call the evening. preceding day, as among the Jews; and for the same reason, because it is said in the Mosaic account of the creation, that "the evening and the morning were the first day." The several services, according to the original or monkish institution, are, 1. *The vespers*, which used to be celebrated a little before sun-set; 2. *The after-vesters*, answering to the *completorium* of the Latin church, which used to be celebrated after the monks had supped, and before they went to bed; 3. *The mesonyealicon*, or midnight service; 4. *The matins* at break of day, answering to the *laudes* of the Romish church; 5. *The first hour* of prayer, or *prima*, at sun-rise; 6. *The third hour*, or *tertia*, at the third hour of the day; 7. *The sixth hour*, or *sexta*, at noon; 8. *The ninth hour*, or *nona*, in the afternoon at the ninth hour of the day. These are called the canonical hours; but it is to be observed, that the *after-vesters* were not added till a late period, before which the reason assigned for the number of services being seven, was, that David saith, "Seven times a-day will I praise thee." When all the psalms and hymns were sung, these daily services could not possibly have been performed in less than twelve or fourteen hours. In the church of Russia, and probably in other branches of the Greek church, there are at present but three services in the day: the *ninth hour*, the *vesters*, and the *after-vesters* making one; the *mesonyealicon*, the *matins*, and *prima*, another; and the *third* and *sixth hour*, with the *communion*, the last. In all the services, except the communion, prayers and praises are offered to some saint; and to the Virgin Mary, almost as often as to God; and in some of the services, after every short prayer uttered by the deacon or the priest, the choir.

Church.

10
Intricate and tedious.

11

Begins in the evening.

Church. his faith he repeats, from beginning to end, the Nicene creed. After a repetition of the formerly repeated questions and answers, the priest prays that the catechumen may be called to God's holy sanctification, and receive the grace of God's holy baptism.

Baptism may be celebrated immediately after the candidate has been made a catechumen, or on any subsequent day at no great distance. In the first part of the form there is not much that is singular, or with which every scholar is not acquainted. After praying that the water may be sanctified, in terms differing little from those which are used in the most respectable Protestant churches, the priest dips his fingers in it, signs it thrice with the sign of the cross; and then blowing upon it, says three times, "Let every adverse power be confounded under the sign of the cross." He then solemnly exorcises it of the dæmon of darkness and all evil spirits; and prays, that "the person to be baptized therein may put off the old man, which is corrupt after the lust of fraud, and may put on the new man after the image of Him that made him. After this, he blows thrice into a vessel of oil of olives held by the deacon, signs it thrice with the sign of the cross; and prays fervently, that it may "become to those who are anointed with faith, and are partakers thereof, the unction of incorruption, the armour of righteousness, the renewing of soul and body, for turning aside all machinations of the devil, and for deliverance from all evil." He then sings allelujah thrice with the people, and pours the oil on the top of the water; and making three crosses with it, says aloud, "Blessed be God, who enlighteneth and sanctifieth every man that cometh into the world, now and forever, even unto ages of ages." The person to be baptized is then presented; and the priest, taking some of the oil with two fingers, and making the sign of the cross on his forehead, on his breast, and betwixt his shoulders, says, "N the servant of God is anointed with the oil of gladness, in the name of the Father, and of the Son, and of the Holy Ghost, now and forever, even unto ages of ages. Amen." He then signs him on the breast and the middle of the back, saying, "For the healing of his soul and body;" then on the ears, saying, "For hearing the faith;" then on the palms of the hands, saying, "Thy hands have made me and fashioned me;" then on the feet, "That he may walk in the way of thy commandments." After the whole body is thus anointed, the priest baptizes him, using the trine immersion; which is unquestionably the most primitive manner. He takes the child in his arms, and holding him upright with his face towards the east, he says, "N the servant of God is baptized (*dipping him the first time*), in the name of the Father, Amen; in the name of the Son (*dipping him again*), Amen; and of the Holy Ghost (*dipping him the third time*), Amen, now and for ever, even unto ages of ages. Amen." After the baptism, the priest wipes his hands, and with the people sings thrice, from beginning to

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end, the 32d Psalm; he then puts upon the baptized person a white garment; saying, "N the servant of God is clothed with the garment of righteousness, in the name of the Father, and of the Son, and of the Holy Ghost, now and for ever, even unto ages of ages (E)." He then prays that he may be delivered from the evil one, and all his insidious snares; that he may be confirmed in the true faith; and that he may preserve his soul in purity and righteousness: and proceeds immediately to anoint him with the *Holy Chrism*.

This chrisin is a very different thing from the oil with which he was anointed previous to baptism, and which was used in the consecration of the baptismal water. It can be prepared only by a bishop, and only on one day in the year, viz. Thursday in Passion-week; and as the anointing with it is substituted in place of the apostolical rite of laying on hands, called *confirmation* in the western churches, great quantities of it are of course prepared at once, and distributed through the different churches of each diocese. The chrisin consists of the following ingredients, which in different proportions are all boiled together, and afterwards solemnly consecrated by the bishop: Fine oil (we suppose of olives), white wine, styrax calamita (F), palud-dew, rose-flowers, black palm-gum, Bahl-gum, majoram, thick and thin oil of nutmegs in very different quantities, oil of cinnamon, oil of cloves, lignum Rhodi, oil of oranges, oil of marjoram, oil of lavender, oil of rosemary, essence of rosemary, cedar, black balsam of Peru, sandarac, whitest mastic, and Venice turpentine. With this holy mixture the baptized person is anointed, the priest making with it the sign of the cross on his forehead, on his eyes, his nostrils, his mouth, both ears, his breast, his hands, and his feet; saying at each part, "The seal of the gift of the Holy Ghost. Amen." Then with the sponsor and the child he goes thrice round the font, turning from the right to the left; the choir, in the mean time, singing, "As many of you as are baptized unto Christ have put on Christ, allelujah."

Seven days after this ceremony is performed, the child is again brought to the church; when the priest, after praying for him, unties his girdle and linen clothes, washes him with clean water, and, sprinkling him, says, "Thou hast been justified, enlightened, sanctified in the name of our Lord Jesus Christ, and with the Spirit of our God." Then taking a new sponge moistened with water, he washes his face, breast, &c.; saying, "Thou hast been baptized, enlightened, anointed, sanctified, washed, in the name of the Father, and of the Son, and of the Holy Ghost, now and for ever, even unto ages of ages. Amen."

The last ceremony appended to baptism is that of ¹⁴the tonsure, or shaving the head of the child in the form of the cross. At what time this rite crept into the church it would not be easy to discover. Some think it received its origin from the religious ceremonies of the Heathen, who certainly rounded the corners

(E) The reader will perceive, that many of these rites and ceremonies are common to the Greek church and the church of Rome in the celebration of the sacrament of baptism.

(F) We quote the words of Dr King, taking it for granted that our readers will pardon our not giving ourselves much trouble to discover, on the present occasion, what particular species or variety of the storax he means by this designation. See STYRAX, *Encycl.*

Church. of their heads, and marred their beards, at a very early period, in honour of their idols (See THEOLOGY, n^o 155. *En cycl.*); and some pious, but foolish Christians, esteemed it highly commendable to transfer to the true God that worship, in a different form, which had been rendered by their ancestors to false deities. Others will have the tonsure to typify the dedication of the person to the service of God; the cutting off of the hair being always considered as a mark of servitude. Be these conjectures as they may, the priest, after the child is baptized, offers up for him several prayers, all alluding to the rite to be performed; and then cuts his hair crosswise, saying, "N the servant of God is shorn, in the name of the Father, and of the Son, and of the Holy Ghost, now and for ever, even unto ages of ages. Amen."

We have given a full account of the manner in which the sacrament of baptism is celebrated among the Greeks, that the reader may have some notion of the childish superstition of that church, with which certain zealous Protestants in England were very desirous, at the beginning of this century, to form a union. There is no occasion for dwelling so long upon their other offices. For the celebration of the Lord's Supper they have three liturgies that are occasionally used, *viz.* that of St Chryostom, which is in ordinary daily use; that of St Basil, used on particular days; and that of the *presanctified*, as it is called, which is used on the Wednesdays and Fridays during the great fast before Easter. Between the liturgies of St Chryostom and St Basil there is no essential difference; and the office of the presanctified is merely a form of dispensing the communion with elements which had been consecrated on the preceding Sunday. We would gladly insert the liturgy of St Chryostom, or at least such an abstract of it as we have given of the form of administering baptism; but as our limits will not permit us to do so, we must refer such of our readers as have any curiosity respecting subjects of this nature to *Dr King's Rites and Ceremonies of the Greek Church.*

It is proper, however, to observe here, that many superstitious ceremonies have been added to the service since the age of St Chryostom, and that no man can compare his genuine works with the liturgy which now goes under his name, and entertain the smallest doubt but that the latter has been greatly, though gradually, corrupted. In the offertory there is a strange ceremony, called *the slaying of the Holy Lamb*, when the priest, taking into his left hand one of the five loaves which are to be consecrated, thrusts a spear into the right side of it; saying, "He was led as a lamb to the slaughter;" then into the left side, adding, "And as a blameless lamb before his shearers is dumb, so he openeth not his mouth:" then into the upper part of the loaf; saying, "In his humiliation his judgment was taken away;" and into the lower part; adding, "And who shall de-

clare his generation?" He then thrusts the spear obliquely into the loaf, lifting it up, and saying, "For his life was taken away from the earth." After this he lays down the loaf, and cutting it crosswise, says, "The Lamb of God, which taketh away the sins of the world, is slain for the life and salvation of the world." All this, and more to the same purpose, is unquestionably modern; but we have no doubt but that the priest uses the words of Chryostom himself, when, in the consecration of the elements, he says, "We offer unto thee this reasonable, this unbloody sacrifice; and we implore, we pray thee, we humbly beseech thee, to send down the Holy Spirit upon us, and those oblations presented unto thee; and make this bread the precious body of thy Christ; and that which is in this cup the precious blood of thy Christ, changing them by thy Holy Spirit."

Dr King observes, that this invocation of the Holy Spirit upon the elements, which in the eastern church is always used after the words of Christ, "This is my body, this is my blood, &c." is inconsistent with the Popish doctrine of transubstantiation: and he is undoubtedly right; for the church of Rome teaches, that the change is made about the middle of the mass, when the priest, taking into his hand first the bread and then the wine, pronounces over each separately the sacred words of consecration; *i. e.* the words of Christ. "It is the office of the priest, in this and in all other sacraments (says a dignitary of that church), only to perform the outward sensible part; but the inward invisible effect is the work of the great God, who accordingly changes the substance of the bread and wine into the body and blood of Christ the very instant that the sacred words of consecration are pronounced by the priest over them." But if this be so, it would be impious, and we believe that by the church of Rome it is deemed impious, to pray afterwards, that God would send down his Holy Spirit to change into the body and blood of Christ elements which he had already changed into that body and blood, in consequence of the priest's pronouncing over them the all-powerful words of Christ. Yet it is certain, that in the present Greek church transubstantiation is as much an article of faith as in the church of Rome; for now every bishop at his consecration declares, in the most solemn manner, that he believes and "understands that the transubstantiation of the body and blood of Christ, in the holy supper, is effected by the influence and operation of the Holy Ghost, when the bishop or priest invokes God the Father in these words, and make this bread the precious body of thy Christ, &c." This is indeed a different account from that of the Latin church of the time at which this portentous change is wrought; but such difference is a matter of very little importance (c). If the change itself be admitted, the consequence must be the same, whether it be supposed to take place when the

(c) Mr Bruce seems to doubt whether transubstantiation be the doctrine of the Abyssinian church, and relates a conversation which he had on the subject with a priest; who solemnly affirmed, that he never believed in the conversion of the substance of the bread and wine into the substance of our Saviour's body and blood. It must be remembered, however, that the priest had at the time a powerful reason for wishing that doctrine not to be true. The Jesuits uniformly attest, that the Abyssinians believe in the real presence; though it must not be forgotten that Ludolf was of a different opinion, and that no man had studied the language of Abyssinia more successfully than he.

Church. the priest pronounces the words of institution, or after he has invoked the descent of the Holy Ghost; in either case it leads to idolatry. It may be proper to mention, that in the Greek church it is deemed essential to the validity of this holy sacrament, that a little warm water be mixed with the wine; that the napkin, which is spread over the holy table, and answers to the *corporale* of the church of Rome, be consecrated by a bishop, and that it have some small particles of the reliques of a martyr mixed in the web, otherwise the eucharist cannot be administered. In this church children may receive the communion immediately after baptism; and the lay communicants, of whatever age, receive both the elements together, the bread being sopped in the cup: The clergy receive them separately.

riage, is called the office of *matrimonial coronation*, from a singular circumstance in it, that of *crowning* the parties. This is done in token of the triumph of continence; and therefore it has, in some places, been omitted at second marriages. Formerly these crowns were garlands made of flowers or shrubs; but now there are kept, in most churches, crowns of silver or some other metal for the celebration of matrimony. At the putting of them on, the priest says, "N, the servant of God, is crowned for the handmaid of God; and "N, handmaid of God, is crowned for the servant of God, in the name of the Father, and of the Son, and of the Holy Ghost;" adding thrice, "O Lord our God, crown them with glory and honour."

Church.

19
The laity
communicate in both
kinds.

20
Confession
in the
Greek
church.

We have observed, that one of the seven *mysterics* or sacraments of the Greek church is *confession*; but among the Greeks it is a much more rational and edifying service than in the church of Rome. In the Greek church the end of confession is the amendment of the penitent; in the church of Rome it is to magnify the glory of the priest. In the former church, the confessors pretend only to abate or remit the penance, declaring the pardon from God alone; in the latter, they take upon them to forgive the sin itself. The Greek church prescribes confession four times in the year to all her members; but the laity, for the most part, confess only once a year previous to receiving the holy communion; and to this they are in Russia obliged by the laws of the empire.

The third ceremony is that of dissolving the crowns on the eighth day; after which the bride is conducted to the bridegroom's house, immediately to enter on the cares of his family.

With respect to discipline and government, the Greek church bears a striking resemblance to that of Rome. In both there is the same division of the clergy into regular and secular; the same spiritual jurisdiction of bishops and their officials, and the same distinction of ranks and offices. In some points the discipline of the Greeks differs from that of the Romans. All orders of secular clergy in the Greek church inferior to bishops are permitted to marry; but celibacy, and the assumption of the monastic habits, are indispensably requisite in those who are candidates for the mitre. The regular clergy, says Mr Dallaway, are generally men of a certain education; whereas the seculars are of the meaner sort, and illiterate in the extreme.

22
Regular
and secular
clergy.

21
Matrimony.

The ceremonies with which matrimony is performed in the Greek church consist of three distinct offices, formerly celebrated at different times, after certain intervals, which now make but one service. First, there was a solemn service, when the parties betrothed themselves to each other, by giving and receiving rings or other presents, as pledges of their mutual fidelity and attachment. The ancient usage was for the man to receive a gold ring and the woman a silver one, which is still alluded to in the rubric, though, in the present practice, the rings are generally both of gold. At this time the dowry was paid, and certain obligations were entered into to forfeit sums in proportion to it, if either of the parties should refuse to ratify the engagement. At this ceremony, called the *μνηστειον*, or *recording of the pledges before witnesses*, the priest gives lighted tapers to the parties to be contracted, making the sign of the cross on the forehead of each with the end of the taper before he deliver it.

In the Greek church there are five orders of clergy promoted by the imposition of hands; but it does not appear that the ordination of the reader, or of the subdeacon, is considered as a sacrament. The forms used in the ordination of deacons, presbyters, and bishops, are serious and significant (*η*), bearing in themselves evidence of great antiquity. The candidate for the deaconate or priesthood kneels before the holy table, and the bishop, laying his right hand on his head, saith, "The divine grace, which healeth our infirmities, and supplieth our defects, promoteth N, the most pious *subdeacon*, to the order of *deacon*;" or, in the case of the priesthood, "The most pious *deacon* to the order of a *presbyter*; let us pray for him, that the Grace of the Holy Spirit may come upon him." It does not appear, from Dr King's account of these offices, that in the Greek church the attending presbyters lay on their hands together with the bishop at the ordination of a

23
Five orders
of clergy.

24
Form of
ordination.

3 I 2

presbyter,

(*η*) We must except those used in the church of Abyssinia, which, according to Mr Bruce, are shamefully indecent. "A number of men and children present themselves at a distance, and there stand, from humility, not daring to approach the *abuna* or bishop. He then asks who these are? and they tell him that they want to be deacons. On this, with a small iron cross in his hand, after making two or three signs, he blows with his mouth twice or thrice upon them; saying, *Let them be deacons*. I saw once (says our author) all the army of Begemder made deacons, just returned from shedding the blood of 10,000 men. With those were mingled about 1000 women, who consequently having part of the same blast and brandishment of the cross, were as good deacons as the rest. In the ordination of priests a little more ceremony is used; for they must be able to read a chapter of St Mark, which they do in a language of which the *abuna* understands not one word. They then give him a brick of salt, to the value perhaps of sixpence, for their ordination; which, on account of this present, the Jesuits maintained to be Simoniacal." There is but one bishop or *abuna* in Abyssinia, and he is always a foreigner, subordinate in his jurisdiction to the patriarch of Alexandria.

Church.

25
Solemn
consecra-
tion of
bishops.

presbyter, as is practised in the church of England; but several bishops lay on their hands together with the archbishop at the consecration of a bishop.

This is indeed a very solemn ceremony. The candidate for the episcopate, who is always an *archimandrite* or *hieromonachus*, i. e. an abbot or chief monk in some monastery, being named to the vacant see, and the election being confirmed, repairs, at the time appointed, to the church where the consecration is to be performed. Being arrived, he is introduced by the proto-pope (1) and proto-deacon to the archbishop and bishops, who are arranged in proper order on a temporary theatre or platform erected in the church for the occasion. He there gives an account of his faith; declares solemnly that he has neither given nor promised money, or any bribe-worthy service, for his dignity; and promises to adhere steadily to the traditions and canons of the eastern church, to visit his diocese regularly, and to oppose strenuously all innovations and heresies, particularly the errors of the Latin church. This being done, the archbishop says, "The grace of the Holy Spirit, through my humility, exalts thee N. archimandrite or hieromonachus, beloved of God, to be bishop of the cities N. N. which God preserve." With much ceremony the bishop elect is then conducted from the theatre, within the rails of the holy altar, where he kneels down with the other bishops, who hold open over his head the holy gospel with the letters inverted, the archbishop saying aloud, "The divine grace, which always healeth our infirmities, and supplieth our defects, by my hand conducteth thee N. archimandrite or hieromonachus, beloved of God, bishop elect of the cities of N. N. which God preserve!—Let us pray therefore for him, that the Grace of the most Holy Spirit may come upon him." Then the priests say thrice, "Lord have mercy upon us;" and while the bishops continue to hold the gospel, the archbishop signs the newly consecrated bishop thrice with the sign of the cross, saying, "In the name of the Father, and of the Son, and of the Holy Ghost, now and for ever, even unto ages of ages. Amen." Then all the bishops putting their right hands on his head, the archbishop prays that he may be confirmed in the office of which they have judged him worthy, that his priesthood may be rendered irreproachable, and that he himself may be made holy and worthy to be heard of God. After this, one of the assisting bishops reads a short litany in a low voice, to be heard only by those within the altar, and the other bishops make the responses. At the end of the litany the archbishop, laying his hand again upon the head of the newly consecrated bishop, prays in very decent and devout terms, that Christ will render him an imitator of himself, the true Shepherd; that he will make him a leader of the blind, a light to those who walk in darkness, and a teacher of infants; that he may shine in the world, and receive at last the great reward prepared for those who contend boldly for the preaching of the gospel. After this the pastoral-staff is delivered to the new bishop, with a very proper and solemn exhortation from the archbishop, to feed the flock of Christ committed to his care.

Church.

The last sacrament of the Greek church is that of the holy oil or *euchelaion*, which is not confined to persons *periculose agrotantibus, et mortis periculo imminente*, like the extreme unction of the Romish church; but is administered, if required, to devout persons upon the slightest malady. Though this ordinance is derived from St James, chap. v. ver. 14, 15. it is by no means deemed necessary to salvation, or obligatory upon all Christians; and it is well that it is not, for seven priests are required to administer it regularly, and it cannot be administered at all by less than three. The oil is consecrated with much solemnity; after which each priest, in his turn, takes a twig, and dipping it in the oil now made holy, anoints the sick person cross-wise, on the forehead, on the nostrils, on the paps, the mouth, the breast, and both sides of the hands, praying that he may be delivered from the bodily infirmity under which he labours, and raised up by the grace of Jesus Christ.

In the Greek, as well as in the Latin church, there is a service, called the divine *lavipedium*, observed on the Thursday, of passion-week, in imitation of our Saviour's humility. At Constantinople Jesus Christ is, on this occasion, personified by the Patriarch, and everywhere else by the bishop of the diocese, and the twelve apostles by twelve regular priests, when a ludicrous contest arises who shall represent Judas; for the name attaches for life. This office is performed at the west end of the church, where an arm-chair is set at the bottom, facing the east, for the bishop; and on each side are placed twelve chairs for the twelve priests, who are to represent the twelve apostles. The prayers and hymns used on this occasion are exceedingly beautiful and appropriate; and when the first gospel, relating our Saviour's washing of his disciples feet, begins to be read, the bishop or patriarch rises up, and takes off his pontifical vestments by himself without assistance. He then girds himself with a towel, and taking a basin of water in his hand, kneels down and washes one foot of each priest, beginning with the youngest; and after having washed it he kisses it. All this is done as the several circumstances are read; and when he comes to the last priest, who is supposed to represent Peter, that priest riseth up and saith, "Lord, dost thou wash my feet?" &c. The bishop answers in the words of our Saviour; and having finished the whole, puts on his garments again, and sits down; and as the second gospel is read (κ), repeats the words of our Saviour, "Know ye what I have done unto you?" &c. The office is certainly ancient, and, if decently performed, must be affecting.

Under the word **PATRIARCHS**, *Encycl.* we have given a sufficient account of the rise of the patriarchates, as well as of the various degrees of rank and authority claimed by the bishops of several other sees in the Greek church. It may be proper to add here, that after the taking of Constantinople by Mohammed II. he continued to the patriarch of that city the same present which the Greek emperors had been accustomed to make—a pastoral staff, a white horse, and four hundred ducats in gold. To the Greek church and the maintenance of its clergy he left indeed ample revenues, which they have gradually sacrificed to their inconstancy,

(1) In the Greek church all parish priests are called *papas* or popes; and the proto-pope is an archpresbyter.
(κ) The first gospel is John xiii. 3—12. The second gospel is John xiii. 12—18.

Church,
Chufan.

cy, their ambition, and their private jealousy. Still, however, the patriarch of Constantinople fills a very lucrative and high office. "Besides the power of nominating the other three patriarchs, and all episcopal dignitaries (says Mr Dallaway), he enjoys a most extensive jurisdiction, comprising the churches of Anatolia, Greece, Wallachia, Moldavia, and the islands of the Archipelago. Since the close of the sixteenth century, the Russian church has claimed a jurisdiction independent of the see of Constantinople; though appeals have been made to that see in cases of extraordinary importance. The influence of the patriarch with the Porte is very extensive, as far as his own nation is concerned. His memorials are never denied; and he can, in fact, command the death, the exile, imprisonment for life, deposition from offices, or pecuniary fine, of any Greek whom he may be inclined to punish with rigour, or who has treated his authority with contempt. On the death of the patriarch the most eager competition is exerted to fill the vacant throne; which, as it is obtained by bribery and intrigue, is of course a very unstable seat to the successful candidate, should another offer to accept the appointment at a lower salary." For a fuller account of the doctrines, discipline, and worship of the Greek church at present, we refer the reader to *King's Rites and Ceremonies of the Greek Church in Russia*, and to *Dallaway's Constantinople ancient and modern* (published in 1797); from which two works this abstract has been mostly taken.

CHUSAN-ISLANDS, a cluster of small islands on the east coast of China, which were visited by Lord Macartney in his course to Peking. Most of these islands seem to be hills rising regularly out of the sea, and rounded at top, as if any points or angles existing in their original formation had been gradually worn off into a globular and uniform shape. Many of them, though close to each other, are divided by channels of great depth. They rest upon a foundation of grey or red granite, some part resembling porphyry, except in hardness. They were, certainly, not formed by the successive alluvion from the earth brought into the sea by the great river at whose mouth they are situated, like the numerous low and muddy islands at the mouth of the Po, and many others; but should rather be considered as the remains of part of the continent thus scooped and furrowed, as it were, into islands, by the force of violent torrents carrying off, further into the sea, whatever was less resistable than the rocks just mentioned. Some of them wore a very inviting aspect; one in particular, called Poo-too, is described as a perfect paradise. This spot was chosen, no doubt, for its natural beauties, and afterwards embellished, by a set of religious men, who, to the number of three thousand, possess the whole of it, living there in a state of celibacy. It contains four hundred temples, to each of which are annexed dwelling-houses and gardens for the accommodation of those monks. This large monastery, as it may be called, is richly endowed, and its fame is spread throughout the empire.

The English East India Company had once a factory at Chufan, the principal of these islands, from which they were many years ago interdicted. This, according to the account of a Chinese merchant who remembered the factory, was not occasioned by any offence given by the English, but by the avarice of the officers

governing at Canton, who draw large sums from the accumulation of foreign trade in that port. Perhaps, too, the excessive jealousy of the Chinese government might fancy danger in the unrestrained communication between foreigners and the subjects of that empire in several of its ports at the same time.

Ting-hai, the chief town of Chufan, resembles Venice, but on a smaller scale. It is surrounded, as well as intersected, by canals, over which are thrown steep bridges, ascended by steps like the Rialto. The streets are narrow, and paved with square flat stones; but the houses, unlike the Venetian buildings, are low and mostly of one story. The ornaments of these buildings are confined chiefly to the roofs, on the ridges of which are uncouth figures of animals in clay, stone, or iron. The town is full of shops, containing chiefly articles of clothing, food, and furniture, displayed to full advantage. Even coffins are painted in a variety of lively and contrasting colours. The smaller quadrupeds, including dogs, intended for food, are exposed alive for sale, as well as poultry, and fish in tubs of water, with eels in sand. When the gentlemen belonging to the embassy were at Ting-hai, they were struck with the number of places where tin-leaf and flicks of odoriferous wood were sold for burning in the temples, which indicated no slight degree of superstition in the people. Superstition, however, made them not idle; for throughout the whole place there was a quick and active industry. Men passed busily through the streets, while not an individual was seen asking alms; and the women were employed in the shops. At Chufan, the number of valuable harbours, or places of perfect security for ships of any burden, is almost equal to the number of islands. This advantage, together with that of their central situation, in respect to the eastern coast of China, and the vicinity of Corea, Japan, Leoo-keoo, and Formosa, attract considerable commerce, especially to Ning-poo, a city of great trade in the adjoining province of Che-chiang, to which all the Chufan islands are annexed. From one port in that province twelve vessels sail annually for copper to Japan.

According to Brookes, Chufan is in N. Lat. 30. 0. E. Long. 124. 0.

CINARA, or CYNARA, which we translate *artichoke*, is, according to Professor Beckmann, the name which was given by the ancients to a plant very different from the artichoke of our kitchen gardens, though he admits that they belong to the same genus. The proofs which he adduces for the truth of his opinion are too tedious to be introduced into this Work, especially as they appear not to us to be absolutely conclusive. We must therefore refer the reader to his *History of Inventions*. The *cinara*, *carduus*, and *scolymus* (see *SCOLYMUS* in this Supplement), were in his opinion species of the *thistle*, of which the *roots* and young *shoots*, as well as the bottom of the *calyx* of the last, were eaten. He has proved indeed, he thinks, that the Greeks and Romans used the pulpy bottom of the calyx, and the tenderest stalks and young shoots of many plants belonging to the thistle kind, in the same manner as we use artichokes and cardoons, but that these latter were unknown to them.

"It appears probable (says he) that the use of these thistles, at least in Italy and Europe in general, was in the course of time laid aside and forgotten, and that the
arti

Chufan,
Cinara.

Cinnabar || **Circular.**
 artichoke, when it was first brought to Italy from the Levant, was considered as a new species of food. It is undoubtedly certain that our artichoke was first known in that country in the 15th century. Hermolaus Barbarus, who died in 1494, relates that this plant was first seen at Venice in a garden in 1473, at which time it was very scarce. About the year 1466, one of the family of Strozza brought the first artichokes to Florence from Naples. Politian, in a letter in which he describes the dishes he found at a grand entertainment in Italy in 1488, among these mentions artichokes. They were introduced into France in the beginning of the 16th century, and into England in the reign of Henry VIII."

The original country of the artichoke is unknown. Linnæus says that it grew wild in Narbonne, Italy, and Sicily, as the cardoon did in Crete; but our author has proved very sufficiently, that with respect to both these facts the great botanist was misinformed. The artichoke is certainly known in Persia; but Tavernier says expressly, that it was carried thither, like asparagus and other European vegetables of the kitchen garden, by the Carmelite and other monks; and that it was only in latter times that it became common.

CINNABAR. See **CHEMISTRY** in this Supplement, n^o 91.

CIRCLE OF CURVATURE, or circle of equicurvature, is that circle which has the same curvature with a given curve at a certain point; or that circle whose radius is equal to the radius of curvature of the given curve at that point.

CIRCLES of Declination are great circles intersecting each other in the poles of the world.

CIRCLE of Diffipation, in optics. See **OPTICS**, *Encycl.* n^o 253.

CIRCLE Equant, in the Ptolemaic astronomy, is a circle described on the centre of the equant. Its chief use is to find the variation of the first inequality.

CIRCLES of Excursion are little circles parallel to the ecliptic, and at such a distance from it, as that the excursions of the planets towards the poles of the ecliptic may be included within them; being usually fixed at about 10 degrees.

CIRCLES of Position, are circles passing through the common intersections of the horizon and meridian, and through any degree of the ecliptic, or the centre of any star, or other point in the heavens; and are used for finding out the situation or position of any star. There are usually six in number, cutting the equinoctial into 12 equal parts, which the astrologers call the *celestial houses*, and hence they are sometimes called *circles of the celestial houses*.

CIRCULAR LINES, a name given by some authors to such straight lines as are divided by means of the divisions made in the arch of a circle; such as the sines, tangents, secants, &c.

CIRCULAR Parts, called, from the use which he first made of them, *Napier's* circular parts, are the five parts of a right-angled or a quadrantal spherical triangle; they are the two legs, the complement of the hypothenuse, and the complements of the two oblique angles.

Concerning these circular parts, Napier gave a general rule in his *Logarithmorum Canonis Descriptio*, which is this; "The rectangle under the radius and the sine of the middle part is equal to the rectangle under the

tangents of the adjacent parts, and to the rectangle under the cosines of the opposite parts. The right angle or quadrantal side being neglected, the two sides and the complements of the other three natural parts are called the *circular parts*, as they follow each other as it were in a circular order. Of these, any one being fixed upon as the middle part, those next it are the adjacent, and those farthest from it the opposite parts."

This rule contains within itself all the particular rules for the solution of right-angled spherical triangles, and they were thus brought into one general comprehensive theorem, for the sake of the memory; as thus, by charging the memory with this one rule alone: All the cases of right-angled spherical triangles may be resolved, and those of oblique ones also, by letting fall a perpendicular, excepting the two cases in which there are given either the three sides, or the three angles. And for these a similar expedient has been devised by Lord Buchan and Dr Minto, which may be thus expressed: "Of the circular parts of an oblique spherical triangle, the rectangle under the tangents of half the sum and half the difference of the segments at the middle part (formed by a perpendicular drawn from an angle to the opposite side), is equal to the rectangle under the tangents of half the sum and half the difference of the opposite parts." By the circular parts of an oblique spherical triangle are meant its three sides and the supplements of its three angles. Any of these six being assumed as a middle part, the opposite parts are those two of the same denomination with it, that is, if the middle part is one of the sides, the opposite parts are the other two, and, if the middle part is the supplement of one of the angles, the opposite parts are the supplements of the other two. Since every plane triangle may be considered as described on the surface of a sphere of an infinite radius, these two rules may be applied to plane triangles, provided the middle part be restricted to a side.

Thus it appears that two simple rules suffice for the solution of all the possible cases of plane and spherical triangles. These rules, from their neatness, and the manner in which they are expressed, cannot fail of engraving themselves deeply on the memory of every one who is a little versed in trigonometry. It is a circumstance worthy of notice, that a person of a very weak memory may carry the whole art of trigonometry in his head.

CIRCULATING DECIMALS. See **DECIMALS** in this Supplement.

CLOCK, a machine for measuring time, of which a description is given in the *Encyclopædia*. For the scientific principles of *clock* and *watch-making*, as well as for a short account of the most valuable constructions, see *WATCH-Making* in this Supplement.

COACH, as we have observed in the *Encyclopædia*, is a very modern invention, if by that word be meant a covered carriage suspended on springs. We learn, indeed, from the laborious researches of Professor Beckmann, that coaches of some kind were known in the beginning of the 16th century; but they were used only by women of the first rank, for the men thought it disgraceful to ride in them. At that period, when the electors and princes did not choose to be present at the meetings of the states, they excused themselves by informing the emperor that their health did not permit them

Coach. them to ride on horseback; and it was considered as a point established, that it was unbecoming for them to ride like women. It is certain, however, that, about the end of the 15th century, the emperor, kings, and princes, began to employ covered carriages on journeys, and afterwards on public solemnities.

The wedding carriage of the first wife of the Emperor Leopold, who was a Spanish princess, cost, together with the harness, 38,000 florins. The coaches used by that Emperor are thus described by Kink: "In the imperial coaches no great magnificence was to be seen; they were covered over with red cloth and black nails. The harness was black, and in the whole work there was no gold. The pannels were of glass, and on this account they were called the *imperial glass coaches*. On festivals the harness was ornamented with red silk fringes. The imperial coaches were distinguished only by their having leather traces; but the ladies in the imperial suite were obliged to be contented with carriages, the traces of which were made of ropes." At the magnificent court of Duke Ernest Augustus of Hanover, there were in the year 1681 fifty gilt coaches with six horses each. So early did Hanover begin to surpass other cities in the number of its carriages. The first time that ambassadors appeared in coaches on a public solemnity was at the imperial commission held at Erfurth in 1613 respecting the affair of Juliers.

In the history of France we find many proofs that at Paris, in the 14th, 15th, and even 16th centuries, the French monarchs rode commonly on horses, the servants of the court on mules, and the princesses, together with the principal ladies, sometimes on asses. Persons of the first rank often sat behind their equerry, and the horse was often led by servants. Carriages, however, of some kind appear to have been used very early in France. An ordinance of Philip the Fair, issued in 1294 for suppressing luxury, and in which the citizens wives are forbid to use carriages (*cars*), is still preserved. Under Francis I. or rather about 1550, somewhat later, there were in Paris for the first time only three coaches.

The oldest carriages used by the ladies in England were known under the now forgotten name of *whirlicotes*. When Richard II. towards the end of the 14th century, was obliged to fly before his rebellious subjects, he and all his followers were on horseback; his mother only, who was indisposed, rode in a carriage. This, however, became afterwards somewhat unfashionable, when that monarch's queen, Ann, the daughter of the Emperor Charles IV. shewed the English ladies how gracefully and conveniently she could ride on a side-saddle. Whirlicotes were laid aside, therefore, except at coronations and other public solemnities. Coaches were first known in England about the year 1580, and, as Stow says, were introduced from Germany by Fitzallen, earl of Arundel. In the year 1598, when the English ambassador came to Scotland, he had a coach with him. Anderfon places the period when coaches began to be in common use about the year 1605. The celebrated duke of Buckingham, the unworthy favourite of two kings, was the first person who rode with a coach and six horses, in 1619. To ridicule this new pomp, the earl of Northumberland put eight horses to his carriage.

Respecting the progress of luxury with regard to coaches, the reader will find much curious information

in the first volume of Professor Beckmann's *History of Cobalt. Inventions*. It is perhaps one of the most entertaining articles in that very learned work. The author, however, with all his labour, has not been able to ascertain the country in which coaches hung on springs were first used; but he seems inclined to give the credit of the invention to Hungary.

COBALT (see *CHEMISTRY-Index*, in this Supplement), is a valuable article to potters and dyers. To fit it for their use, it is first roasted and freed from the foreign mineral bodies with which it is united: it is then well calcined, and sold either mixed or unmixed with fine sand under the name of zaffer (*zaffera*); or it is melted with siliceous earth and potashes to a kind of blue glass called *smalt*, which when ground very fine is known in commerce by the name of *powder blue*. All these articles, because they are most durable pigments, and those which best withstand fire, and because one can produce with them every shade of blue, are employed above all for tinging crystal and for enamelling; for counterfeiting opaque and transparent precious stones, and for painting and varnishing real porcelain and earthen and potters ware. This colour is indispensably necessary to the painter when he is desirous of imitating the fine azure colour of many butterflies and other natural objects; and the cheaper kind is employed to give a blueish tinge to new-washed linen, which so readily changes to a disagreeable yellow, though not without injury to the health as well as to the linen.

Professor Beckmann, in his *History of Inventions*, gives the following account of the paint prepared from cobalt. "About the end of the 15th century cobalt appears to have been dug up in great quantity in the mines on the borders of Saxony and Bohemia, discovered not long before that period. As it was not known at first to what use it could be applied, it was thrown aside as a useless mineral. The miners had an aversion to it, not only because it gave them much fruitless labour, but because it often proved prejudicial to their health by the arsenical particles with which it was combined; and it appears even that the mineralogical name *cobalt* then first took its rise. At any rate, I have never met with it before the beginning of the 16th century; and Mathesius and Agricola seem to have first used it in their writings. Frisch derives it from the Bohemian word *kow*, which signifies *metal*; but the conjecture that it was formed from *cobalus*, which was the name of a spirit that, according to the superstitious notions of the times, haunted mines, destroyed the labours of the miners, and often gave them a great deal of unnecessary trouble, is more probable; and there is reason to think that the latter is borrowed from the Greek. The miners, perhaps, gave this name to the mineral out of joke, because it thwarted them as much as the supposed spirit, by exciting false hopes, and rendering their labour often fruitless. It was once customary, therefore, to introduce into the church service a prayer that God would preserve miners and their works from *kobolts* and spirits.

"Respecting the invention of making an useful kind of blue glass from cobalt, we have no better information than that which Klotzsch has published from the papers of Christian Lehmann. The former, author of an historical work respecting the upper district of the mines in Misnia, and a clergyman at Scheibenberg, collected

with

Cobalt.

with great diligence every information that respected the history of the neighbouring country, and died at a great age in 1688. According to his account, the colour-mills at the time when he wrote were about 100 years old; and as he began first to write towards the end of the thirty years war, the invention seems to fall about 1540 or 1560. He relates the circumstance as follows: 'Christopher Schurer, a glass-maker at Platten, a place which belongs still to Bohemia, retired to Neudeck, where he established his business. Being once at Schneeberg, he collected some of the beautiful coloured pieces of cobalt which were found there, tried them in his furnace; and finding that they melted, he mixed some cobalt with glass metal, and obtained fine blue glass. At first he prepared it only for the use of the potters; but in the course of time it was carried as an article of merchandise to Nuremberg, and thence to Holland. As painting on glass was then much cultivated in Holland, the artists there knew better how to appreciate this invention. Some Dutchmen therefore repaired to Neudeck, in order that they might learn the process used in preparing this new paint. By great promises they persuaded the inventor to remove to Magdeburg, where he also made glass from the cobalt of Schneeberg; but he again returned to his former residence, where he constructed a handmill to grind his glass, and afterwards erected one driven by water. At that period the colour was worth 7½ dollars per cwt. and in Holland from 50 to 60 florins. Eight colour mills of the same kind, for which roasted cobalt was procured in casks from Schneeberg, were soon constructed in Holland; and it appears that the Dutch must have been much better acquainted with the art of preparing, and particularly with that of grinding it, than the Saxons; for the Elector John George sent for two colour-makers from Holland, and gave a thousand florins towards the enabling them to improve the art. He was induced to make this advance chiefly by a remark of the people of Schneeberg, that the part of the cobalt which dropped down while it was roasting contained more colour than the roasted cobalt itself. In a little time more colour-mills were erected around Schneeberg. Hans Burghard, a merchant and chamberlain of Schneeberg, built one, by which the eleven mills at Platten were much injured. Paul Nordhoff, a Frieslander, a man of great ingenuity, who lived at the Zwittermill, made a great many experiments in order to improve the colour; by which he was reduced to so much poverty that he was at length forced to abandon that place, where he had been employed for ten years in the colour-manufactory. He retired to Annaberg, established there in 1649, by the assistance of a merchant at Leipzig, a colour-manufactory, of which he was appointed the director; and by these means rendered the Annaberg cobalt of utility. The consumption of this article, however, must have decreased in the course of time; for in the year 1659, when there were mills of the same kind at more of the towns in the neighbourhood of mines, he had on hand above 8000 quintals.' Thus far Lehmann."

Kofler says, that the Bohemian cobalt is not so good as that of Misnia, and that its colour is more like that of ashes. We trust, however, that the qualities of foreign cobalt shall soon be a matter of little importance to the British artist, as a rich mine of this mineral has lately been discovered near Penzance in Cornwall.

Coffee.

COFFEA, the *COFFEE-Tree*, is a plant which has been botanically described in the Encyclopædia Britannica, where some account is likewise given of the modes of cultivating it, as well as of the qualities of its fruit. Since that account, however, was published, two works have fallen into our hands, from which we deem it our duty to make such extracts as may not only correct some mistakes which we had committed, but also communicate useful information to the public.

In our former article we adopted the common opinion, that the coffee produced in Arabia is so greatly superior to that which is raised everywhere else, that it is vain to think of cultivating the plant to any extent in the West India islands. We are happy to find that this is a vulgar error. In the year 1783, when the cultivation of coffee was not so well understood in Jamaica as at present, some samples from that island were produced in London, and pronounced by the dealers to be equal to the very best brought from the East. "Two of the samples were equal to the best Mocha coffee, and two more of them superior to any coffee to be had at the grocers shops in London, unless you will pay the price of *picked* coffee for it, which is two shillings per pound more than for that which they call the *best* coffee. All the rest of the samples were far from bad coffee, and very little inferior, if at all, to what the grocers call *best* coffee*."

If this be so, it surely becomes the legislature of Great Britain to encourage the cultivation of coffee in the West Indies, especially as it thrives best in soil which is not fit for the sugar-cane, and may be raised in considerable quantities by those who are not able to stock a sugar plantation. The encouraging every article which increases the intercourse with our colonies is increasing our commerce. The payment for all the staples of the West Indies is made in our manufactures; the sale of which must increase in proportion to the numbers that are employed in the cultivation of what is bartered for them. Our West India islands, without draining us of specie or bullion, can supply us with many of those very articles for which we are drained in other parts of the world, and particularly with coffee.

To give a detailed account of the introduction of the coffee-tree into the West Indies, would swell this article to very little purpose. According to Boerhaave, a Dutch governor was the first person who procured fresh berries from Mocha, and planted them in Batavia; and in the year 1690 sent a plant from thence to Amsterdam, which came to maturity, and produced those berries which have since furnished all that is now cultivated in the West Indies.

In 1714 a plant from the garden of Amsterdam was sent by Mr Pancras, a burgomaster and director of the botanic garden, as a present to Louis XIV. which was placed in the garden at Marly. In 1718, the Dutch began to cultivate coffee in Surinam; in 1721, the French began to cultivate it at Cayenne; in 1727, at Martinico; and in 1728, the English began to cultivate it in Jamaica.

As it has been more cultivated in the French West India islands than in the British, it may be of importance to our colonists to be made acquainted with the practice of the French planters. Accordingly Dr Laborie, a royalist of St Domingo, has lately published a volume for their instruction on this subject; in which

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* Moseley's
Treatise on
Coffee.

Coffea. are many judicious observations, the result of long experience, respecting the soil fit for a coffee plantation; the various establishments necessary; the cultivation of the coffee-tree through the several stages of its growth and duration; and the management and use of the negroes and cattle.

With respect to soil, it is a fact, says he, beyond contradiction, that low lands, and even the mountains near the champaign country, are less proper for the production of coffee, than lands which are high and at a distance from the sea. The coffee-tree delights in a comparatively cool climate, and in an open and permeable virgin soil; and is hurt by the parching destructive air of the sea. The soil on the mountains of St Domingo consists generally of a bed of mould more or less deep; but which, for the production of coffee-trees, ought not to be less than four or five feet. If the declivity be gentle, the softest and most friable earth is preferable to all others; but in steep grounds a firm though not clayey soil, mixed with a proportion of gravel or small stones, through which the water may find an easy way, is the most desirable. The colour of the ground is of little consequence, though such as is somewhat reddish is generally to be preferred. With regard to exposure, the north and west are the most eligible in low and hot situations, because these exposures are the coolest; and on the highest mountains the south and east are to be chosen, because they are the hottest. On the whole, neither the highest nor the lowest situations are the best, but those which are considerably above the middle of the mountains.

Whatever be the planter's circumstances in point of fortune, and our author thinks that he ought not to undertake a settlement without the command of 3000 or 4000 pounds sterling, he ought not to set out with a great number of negroes. If he cannot command a plentiful supply of victuals from some contiguous plantation, six, or at the most twelve, male negroes, with one or two women, will be found sufficient to make the first essay. After building two huts, one for the master or overseer and the other for the slaves, they are to commence their operations by cutting away the underwood and creeping plants with the bill, and felling the trees. The trees are to be cut as low as possible, but the roots are to be left in the ground, because they preserve the soil during the first period of culture; and in burning this mass of wood and shrubs, the only way sometimes of clearing the ground, care must be taken that the fire be nowhere so violent as to convert the soil into the consistence of brick, which it is very apt to do if the soil be clayey. Amid the coffee-trees, after they are planted, may be sown beans, maize, and all kinds of esculent plants, pot herbs, and roots; but particular care must be taken to remove from these plantations all creeping plants, such as melons, yams, potatoes, gourds, and more especially tobacco, which multiplies to a vast extent, and exhauts the ground.

In St Domingo the most approved method of planting the coffee-tree is in straight rows crossing each other at right angles, and the distance between the plants is regulated by the quality and exposure of the ground. The richer the soil, the exposures being the same, and the cooler the exposure, the quality of the soil being the same, the farther must the trees be planted asunder. If on the north and west the ground be good, plant still

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Coffea. farther; but, on the contrary, if to the east or south it be light (which it generally is), plant still nearer. Thus if it be proper on a south or east exposure to plant at the distance of six feet, it will be necessary to plant at the distance of seven on a west or north exposure, if the ground be of the same quality as in the other situations.

Though coffee, like all other vegetables, grows from the seed, Dr Laborie advises, in the forming of large plantations, to make use of saplings reared in nurseries; and the situation fittest for a nursery is a plain, or at least a ground of gentle ascent, where the mould is crumbly. In forming a nursery, some plant the whole cherry; but our author recommends the taking off the skin, and washing the separated seeds; in which we suspect that he is mistaken, as his practice is certainly a deviation from nature. The nursery must be kept very clear of weeds, and neither corn nor any thing else sown in it.

The best season for transplanting the saplings is during the genial rains of April and May, when great attention is required, as the treasures of future harvests are at stake. Those plants are the fittest for being removed which, in the language of our author, are *crowned*, or have each four little boughs; and, if the seeds were fresh and sown in furrows about an inch from each other, this perfection is generally attained in the course of a year. The saplings must not be pulled up by force, but carefully raised by means of a flat, sharp, iron shovel, thrust deep under their roots; and the sooner they are planted, after being taken up, the better.

In planting, the first thing to be done is to thrust into the ground a dibble, or sharp pointed stick, round which a hole is dug from nine to twelve inches in diameter, and from fifteen to eighteen in depth. Then a quantity of the mould taken out of the hole is thrown back into it, till its depth be diminished about four or six inches; and the plant being supported with the left hand, in the middle of the hole, while the end of its straight root, which our author calls its pivot, touches lightly the new bed, the surrounding mould is with the right hand thrown in, to the height of six inches. This being lightly pressed down with both hands, more earth is thrown in and pressed in the same manner, care being taken not to hurt, or bend, or displace the sapling, which must be set so deep that its two inferior branches be rather below the level of the ground. On this account three or four inches of the hole are left open, which, by the time that these branches rise above its margin, are filled up by the surrounding earth. The business is finished by sinking the sharp-pointed stick at the upper margin of the hole, where it serves as a small fence to the infant tree. In hot situations plantain trees are intermingled with the coffee trees for the purpose of shade and coolness. They are usually placed in every fourth or sixth row, as the trees are more or less distant, and the exposure more or less hot.

To the business of planting very soon succeeds that of weeding; for there is hardly any plant to which weeds are so pernicious as the coffee-tree: they cause it to grow yellow, fade, wither, and perish. Where the ground slopes much, especially if the soil be soft and friable, the weeds must be taken up by the hand; for if they be rooted out by the hoe, the soil will be so loosened that the rains will sweep it away. Some

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weeds, however, from the depth of their roots must be dug up; and when that is the case the earth must be carefully returned and pressed down. If, in weeding, any saplings be found withered, others of the same size must be brought from the nursery and planted in their stead, with what our author calls their clod, *i. e.* with the earth of the nursery adhering to their roots. If any sapling be found broken or twisted, it must be cut close by the ground in a sloping direction, the cut surface facing the north, and it will soon put forth suckers, of which the best only need be preserved. In plantations of eighteen or twenty months old trees are often found with yellow, withered leaves, of which the cause is sometimes a premature load of fruit, which must therefore be instantly removed or the tree will perish. If, after this, it begin not in a few days to recover, it is probably eaten at the roots by a large white worm resembling a slug. In that case the tree must be removed, the worm taken out, and before another tree be planted in its stead, a large hole must be made in the ground, exposed to the influence of the sun at least for a fortnight.

The natural height of the coffee tree is from 15 to 18 feet; and if left to itself it would have the form of most other trees, *i. e.* a naked trunk and a branchy head. This is prevented by what the planters call *stopping*; which is performed by cutting off the top of the tree when it has arrived at the proper height, which varies according to circumstances. In the best soil and most genial exposure, it is suffered to grow to the height of five feet, and in the worst stopped at two; but under the same aspect, and on ground of the same quality, all the trees ought to be stopped at the same height. This operation of stopping is very apt to make the trees put forth superfluous branches, which renders them inaccessible to the genial warmth of the sun, and, of course, deficient in the powers of fructification. These must be *plucked* away while yet tender; for if they be suffered to grow till it become necessary to cut them, a number of sprouts succeed; whereas, when they are plucked, the wound soon cicatrizes, and nothing follows.

The saw and the knife, however, must sometimes be used; for when trees grow old their heads are apt to spoil; superfluous branches may have been left upon them through neglect; a bough may have been broken by accident; or branches may be spent by too great a load of fruit. In all these cases recourse must be had to pruning, which should be performed immediately after crop, and in such a manner as that the tree, when it puts forth its new branches, may still have as much as possible its natural or former appearance. This will be accomplished by cutting the withered bough immediately above a knot, whence a good secondary branch is put forth, which may be easily trained into the proper shape. Our author directs the cut to be always made so as that the sloping surface shall face the north; by which exposure it will escape the injury which it would otherwise receive from the excessive heat of the sun. This is a good advice; but it would still be an improvement on it to treat the wound with Forfyth's or Hit's plaster, which we have described elsewhere (See *Encycl.* Vol. XVIII. page 562). When the tree is completely pruned, the moss and other excrescences must be scraped from the trunk with a wooden knife, great care being taken not to injure the bark.

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After pruning follows what is called *nipping*. This is nothing more than the removal of those superfluous small twigs which are sent forth from every cut surface in such numbers as would soon exhaust the tree; and it is called *nipping*, because they are plucked away by the hand, and not cut by the knife. It is needless to add, that when the ground begins to be impoverished, it must be enriched by proper manure. This is known to every husbandman both in Europe and in the West Indies; but it is not perhaps so generally known that the weedings, and chiefly the red skins of coffee, when gathered into pits, are, in process of time, converted into a black mould, which our author says makes the very best manure.

"The fruit of the coffee, when perfectly ripe, appears like a small oval cherry. Under a red and shining skin a whitish clammy luscious pulp presents itself, which generally incloses two seeds. These seeds have one side flat, the other hemispherical. The first is marked with a longitudinal fissure, and the flat sides are applied to each other. When the seeds are opened, they are found covered with a white, ligneous, brittle membrane, denominated *parchment*; on the inside of which is another silver-coloured membrane, exceedingly thin, and seeming to originate from the fissure of the seeds. Sometimes the cherry has but one seed or grain, which then is in the form of a small egg. This is peculiar to old decayed trees, or to the extremities of some small branches."

The business of preparation consists in taking the seed from its covering, in drying, and in cleaning it so as to have every advantage at market. Our author thinks that the best method of preparing the coffee is to strip the seed of its outer skin immediately on its being pulled, and to dry it in its parchment. The process has been already described in the *Encyclopædia*; but we believe it to be an injudicious one. We have the authority of a very eminent botanist*, well acquainted with all the vegetable productions of the West Indies, to say, that the improvement which we have there mentioned, as proposed by Mr Miller, is greatly preferable to Dr Laborie's practice. Indeed he himself admits, that coffee dried in the cherry is more heavy than when dried in parchment, and that it generally has a higher flavour. Nay, he says expressly, that "if a planter wants to have coffee of the first quality, either for himself or for his friends, he must set a part a number of his oldest trees, and not gather the fruit till it is ripened into *dryness*. It is in that manner, he believes, that the Arabians in Yemen make their little harvests; and he declares, that coffee thus nourished on the tree to the last moment, must have every perfection of which it is capable." His only plausible objection is, that the trees are soon exhausted when the fruit is left so long upon them; but doubtless this exhaustion might be retarded by proper manure.

The chemical analysis of coffee evinces that it possesses a great portion of mildly bitter and lightly astringent gummous and resinous extract; a considerable quantity of oil; a fixed salt; and a volatile salt.—These are its medicinal constituent principles. The intention of torrefaction is not only to make it deliver those principles, and make them soluble in water, but to give it a property it does not possess in the natural state of the berry. By the action of fire, its leguminous taste and

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the aqueous part of its mucilage are destroyed; its saline properties are created and disengaged, and its oil is rendered empyreumatic.—From thence arises the pungent smell, and exhilarating flavour, not found in its natural state.

The roasting of the berry to a proper degree requires great nicety: Du Four justly remarks, that the virtue and agreeableness of the drink depend on it, and that both are often injured in the ordinary method. Bernier says, when he was at Cairo, where it is so much used, he was assured by the best judges, that there were only two people in that great city, in the public way, who understood the preparing it in perfection. If it be under-done, its virtues will not be imparted, and in use it will load and oppress the stomach:—If it be overdone, it will yield a flat, burnt, and bitter taste, its virtues will be destroyed, and in use it will heat the body, and act as an astringent.

Fourteen pounds weight of raw coffee is generally reduced, at the public roasting houses in London, to eleven pounds by the roasting; for which the dealer pays seven pence half-penny, at the rate of five shillings for every hundred weight. In Paris, the same quantity is reduced to ten pounds and an half. But the roasting ought to be regulated by the age and quality of the coffee, and by nicer rules than the appearance of the fumes, and such as are usually practised: therefore the reduction must consequently vary, and no exact standard can be ascertained. Besides, by mixing different sorts of coffee together, that require different degrees of heat and roasting, coffee has seldom all the advantages it is capable of receiving to make it delicate, grateful, and pleasant. This indeed can be effected no way so well as by people who have it roasted in their own houses, to their own taste, and fresh as they want it for use. The closer it is confined at the time of roasting, and till used, the better will its volatile pungency, flavour, and virtues, be preserved.

The mode of preparing this beverage for common use differs in different countries, principally as to the additions made to it.—But though that is generally understood, and that taste, constitution, the quality of the coffee, and the quantity intended to be drunk, must be consulted, in regard to the proportion of coffee to the water in making it—yet there is one material point, the importance of which is not well understood, and which admits of no deviation.

The preservation of the virtues of coffee, particularly when it is of a fine quality, and exempt from rankness, as has been said, depends on carefully confining it after it has been roasted; and not powdering it until the time of using it, that the volatile and ethereal principles, generated by the fire, may not escape. But all this will signify nothing, and the best materials will be useless, unless the following important admonition is strictly attended to; which is, that after the liquor is made, it should be bright and clear, and entirely exempt from the least cloudiness or foul appearance, from a suspension of any of the particles of the substance of the coffee.

(A) It is not to coffee alone that this reflection is confined; every article we use as a diluter demands the same attention. Malt liquors, particularly small beer, which in this respect is much neglected, ought always to be carefully fined. The saculent matter entangled by the mucilage of the malt is hurtful to digestion, and detrimental to health.

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There is scarcely any vegetable infusion or decoction whose effects differ from its gross origin more than that of which we are speaking. Coffee taken in substance causes oppression at the stomach, heat, nausea, and indigestion: consequently a continued use of a preparation of it, in which any quantity of its substance is contained, besides being disgusting to the palate, must tend to produce the same indispositions. The residuum of the roasted berry, after its virtues are extracted from it, is little more than an earthy calx, and must therefore be injurious.

The want of attention to this circumstance has been the cause of many of the complaints against coffee, and of the aversion which some people have to it; and it is from this consideration that coffee should not be prepared with milk instead of water, nor should the milk be added to it on the fire, as is sometimes the case, for economical dietetic purposes, where only a small quantity of coffee is used, as the tenacity of the milk impedes the precipitation of the grounds, which is necessary for the purity of the liquor, and therefore neither the milk nor the sugar should be added until after it is made with water in the usual way, and the clarification of it is completed (A).—The milk should be hot when added to the liquor of the coffee, which should also be hot, or both should be heated together, in this mode of using coffee as an article of sustenance.

If a knowledge of the principles of coffee, founded on examination and various experiments, added to observations made on the extensive and indiscriminate use of it, cannot authorise us to attribute to it any particular quality unfriendly to the human frame; if the unerring test of experience has confirmed its utility, in many countries, not exclusively productive of those inconveniences, habits, and diseases, for which its peculiar properties seem most applicable—let those properties be duly considered; and let us reflect on the state of our atmosphere, the food and modes of life of the inhabitants, and the chronical infirmities which derive their origin from these sources, and it will be evident what salutary effects might be expected from the general dietetic use of coffee in Great Britain.

COFFER-DAMS, or *Batardeaux*, in bridge-building, are enclosures formed for laying the foundation of piers, and for other works in water, to exclude the surrounding water, and so prevent it from interrupting the workmen.

COLCHESTER, the chief town in Essex, is described in the *Encyclopædia Britannica*; but the description is in many respects erroneous. The following account of it was sent to us by an obliging correspondent, who is desirous that the place of his nativity may be accurately described in this Supplement.

Colchester is pleasantly situated upon an eminence, gradually rising on the south side of the river Colne. It is the ancient *Colonia Camulodunum*, from which word *Colonia*, both the town and the river Colne received their names. The Saxons called it *Colnecestre*. That it flourished under the Romans, several buildings full of their bricks, and innumerable quantities of coin

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dug up in and about it, fully evince. In the year 1763, a curious tessellated or mosaic pavement was found in the garden of the late Mr Barnard, surgeon in the High Street, now the property of Mr John Wallis, about three feet under the surface of the earth. The emperor Constantine the Great was born here, his mother Helen being daughter of Cool, governor or king of this district under the Romans. She is said to have found out the cross of Christ at Jerusalem; and on that account the arms of this town are a cross regulee between three ducal coronets, two in chief and one in base, the coronet in base passing through the cross.

The walls wherewith the town was encompassed are still tolerably entire on the south, east, and west sides, but much decayed on the north side: they are generally about nine feet thick. By a statute of King Henry VIII. this town was made the see of a suffragan bishop.

This town is the most noted in England for making of baize; it is also of special note for candying the eringo roots, and for oysters.

In the conclusion of the civil war 1648, this town suffered a severe siege of ten weeks; and the besieged making a very resolute defence, the siege was turned into a blockade, wherein the garrison and inhabitants suffered the utmost extremity of hunger, being reduced to eat horse-flesh, dogs, and cats, and were at last obliged to surrender at discretion, when their two valiant chief officers, Sir Charles Lucas and Sir George Lisle, were shot under the castle walls in cold blood. Colchester is a borough by prescription, and under that right sends two members to parliament, all their charters being silent upon that head. The charter was renewed in 1763. The town is now governed by a mayor, recorder, 12 aldermen, 18 assistants, and 18 common-council men. Quarter-sessions are held here four times in the year.

The famous abbey gate of St John is still standing, and allowed to be a surprising, curious, and beautiful piece of Gothic architecture, great numbers of persons coming from remote parts to see it. It was built, together with the abbey, in 1097, and Gudo, steward to King William Rufus, laid the first stone.

St Ann's chapel, standing at the east end of the town, is valuable in the esteem of antiquarians as a building of great note in the early days of Christianity, and made no small figure in history many centuries past. It is now pretty entire.

St Botolph's priory was founded by Ernulphus in the reign of Henry I. in the year 1110. It was demolished in the wars of Charles I. by the parliament army under Sir Thomas Fairfax. The ruins still exhibit a beautiful sketch of ancient masonry, much admired by the lovers of antiquities. The castle is still pretty entire, and is a magnificent structure, in which great improvements have of late been made. Here is an excellent and valuable library.

The markets, which are on Wednesday and Saturday, are very well supplied with all kinds of provisions. There are no less than six dissenting meeting-houses in this town. Colchester is 51 miles from London. It had 16 parish churches, in and out of the walls, but now only 12 are used, the rest being damaged at the siege in 1648.

COLOURS. See PIGMENTS in this Supplement. *Accidental Colours*, a name given to a very curious

optical phenomenon, which was first, we believe, attended to by Buffon. That philosopher wrote a short paper on it, which was published in the Memoirs of the Academy of Sciences for the year 1743.

If a person look steadfastly and for a considerable time at a small red square painted upon white paper, he will at last observe a kind of green-coloured border surround the red square. If he now turn his eyes to some other part of the paper, he will see an imaginary square of a delicate green bordering on blue, and corresponding exactly in point of size with the red square. This imaginary square continues visible for some time, and indeed does not disappear till the eye has viewed successively a number of new objects. It is to this imaginary square that the improper name of *accidental colour* has been given. If the small square be yellow, the imaginary square or accidental colour is blue: the accidental colour of green is red; of blue, yellow; of white, black; and on the contrary, that of black is white.

The first person, as far as we know, who gave a satisfactory explanation of these phenomena was Professor Scherffer of Vienna, whose dissertation, translated by Mr Bernoulli, has been published in the 26th volume of the Journal de Physique.

In order to understand these phenomena, let us recollect, in the first place, that light consists of seven rays, namely, red, orange, yellow, green, blue, indigo, violet; that whiteness consists in a mixture of all these rays: and that those bodies which reflect but very little light are black. Those bodies that are of any particular colour, reflect a much greater quantity of the rays which constitute that particular colour than of any other rays. Thus red bodies reflect most red rays; green bodies, most green rays, and so on.

Let us recollect, in the second place, that when two impressions are made at the same time upon any of our organs of sensation, one of which is strong and the other weak, we only perceive the former. Thus if we examine by the prism the rays reflected by a red rose, we shall find that they are of four kinds; namely red, yellow, green, and blue. In this case, the impression made by the red rays makes that made by the others quite insensible. For the same reason, when a person goes from broad day light into an ill-lighted room, it appears to him at first perfectly dark, the preceding strong impression rendering him for sometime incapable of feeling the weaker impression.

With the assistance of these two remarks, it will not be difficult to explain the phenomena of accidental colours. When a person considers attentively for some time a white square lying on any black substance (paper for instance), it is evident that the part of the retina on which the white square is painted, receives a stronger impression than any other part; at least the greatest number of rays strike upon it. A weaker impression, therefore, will act on it with much less force than upon the rest of the retina. Consequently, when the eye is turned from the white square to some other part of the black paper, a square is perceived of the same size with the white square, and much blacker than any other part of the paper: this is evidently in consequence of the weaker impression made by the rays reflected by the black paper upon that part of the eye previously fatigued by the copious reflection from the white square. For the very same reason, if, after looking for a sufficient

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cient time at a white square lying on a black ground, we turn our eyes upon a sheet of white paper, we perceive a very well defined black square. In this case, the part of the retina already fatigued is not so sensible to the rays reflected by the white paper as the other parts of it which have not been fatigued. The reason then that black is the accidental colour of white is sufficiently evident.

On the contrary, when we look a sufficient time at a black square lying upon a white ground, if we turn our eyes to any other part of the white paper, or even upon black paper, we shall perceive a small square answering to the black square, and much brighter than any other part of the paper: evidently because that part of the retina on which the black square was painted being less fatigued is more susceptible of impressions than any other part of the eye. Thus we see why the accidental colour of black is white, and why that of white on the contrary is black. These facts, indeed, have been long known, and they have been generally explained in this manner.

When a person has looked for a sufficient time at a red square placed on a sheet of white paper, and then turns his eyes to another part of the paper, that part of the retina on which the red was painted being fatigued, the red rays reflected from the white paper cease to make any sensible impression on it, and consequently there will be seen upon the white paper a square similar to the red square, and the colour of which is that which would result from the mixture of all the rays of light except the red. In general, therefore, the accidental colour is the colour which results from the mixture of all the rays of light, those rays excepted which are the same with the primitive colour.

Now, in order to discover the accidental colours, let us recollect the manner which Newton employed to determine the colour which results from the mixture of several others, the species and quantity of which are known. He did it by dividing the circumference of a circle, so that the arches are to one another in the proportion of a string shortened by degrees, in order to find one after another the notes of an octave; which is nearly the proportion that the different rays occupy when light is decomposed by means of the prism. Or suppose the circumference of the circle, as usual, divided into 360 degrees, the different rays, according to Benvenuto, should occupy the following arches:

Red,	-	-	-	-	45°
Orange,	-	-	-	-	27
Yellow,	-	-	-	-	48
Green,	-	-	-	-	60
Blue,	-	-	-	-	60
Indigo,	-	-	-	-	40
Violet,	-	-	-	-	80

Let us now compare the action of colours on one another with that of different weights; and for that purpose let us suppose each colour concentrated in the centre of gravity of its arch. In order to find the colour resulting from any mixture, we have only to find the common centre of gravity of the arches which represent the different colours: The colour resulting from the mixture will be that of the arch to which the common centre of gravity approaches nearest. And if that common centre of gravity is not in the straight line which joins the centre of the circle, and the centre of gravity

of the arch to which it is most contiguous, the resulting colour will approach more or less to the colour of the contiguous arch towards which the line, passing through the centre of the circle, and the common centre of gravity of the arches, falls. And farther, the resulting colour will be more or less deep according to the distance of the common centre of gravity from the centre of the circle.

In the case under consideration at present, namely, to determine the different accidental colours, the application of this method is remarkably easy; because only one of the seven primitive colours is excluded, and consequently the six colours from the mixture of which we wish to know the resulting colour are all contiguous. For it is evident, that the sum of the six arches, representing these six colours, will be divided into two equal parts by the line which passes through the centre of the circle and their common centre of gravity; and that if the same line be produced till it reaches the circumference of the circle on the other side, it will also divide the arch representing the seventh or omitted colour into two equal parts. Let us suppose, for instance, that the violet is omitted, and that we wanted to know the colour resulting from the mixture of the other six colours, we have only to bisect the arch representing the violet, and from the point of section to draw a diameter to the circle, the arch of the circle opposite to the violet through which the diameter passes will indicate the colour of the mixture. The arch representing the violet being 80°, let us take the half of it, which is 40°, and let us add to it 45° for the red, 27° for the orange, and 48° for the yellow, we shall have 160°, which wants 20° of half the circumference of the circle. If now we add the 60° for the green, the sum total will be 220°, considerably more than half the circumference; consequently the common centre of gravity is nearest the green arch; but it falls 10° nearer the yellow than the straight line which joins the centre of the circle and the centre of gravity of the green arch. Hence we see that the resulting colour will be green, but that it will have a shade of yellow.

It is evident, then, that the accidental colour of violet must be green with a shade of yellow; and this is actually the case, as any one may convince himself by making the experiment.

Suppose, now, we wanted to know the accidental colour of green, or, which is the same thing, the colour resulting from the mixture of all the primitive rays except the green. The green arch is 60°, the half of which is 30°; if to this we add 60° for the blue arch, and 40° for the indigo arch, we shall have 130°, or 50° degrees less than a semicircle. If to this we add the violet arch, which is 80°, we shall have 30° more than the semicircle; consequently the common centre of gravity falls nearest the violet, and it is 10° nearer the red arch than is the centre of gravity of the violet arch. Hence we know that the accidental colour of green will be violet or purple, with a shade of red: And experiment confirms this.

Buffon observed that the accidental colour of blue was reddish and pale. Let us see whether we shall obtain the same result from our method. Let us suppose that Buffon employed a light blue. In that case, if to 30, the half of the blue arch, we add 80 for the green, 48 for the yellow, and 27 for the orange, we shall have 165°, or 15° less than half the circumference of the circle.

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circle: Consequently the common centre will fall nearest the red arch, but within 15° of the orange. The accidental colour must therefore be red, with a shade of orange; or, which is the same thing, it must be a pale red.

In the same manner we may discover, that the accidental colour of indigo is yellow, inclining a good deal to orange; and that the accidental colour of indigo and blue together is orange, with a strong shade of red. Both of which correspond accurately with experiment.

It would be easy to indicate, in the same manner, the accidental colour of any primitive colour, if what has been said were not sufficient to explain the cause of accidental colours, and to show that their phenomena correspond exactly, both with the Newtonian theory of optics, and with what we know to be laws of our sensations in other particulars.

From the theory above given, which is that of Professor Scherffer, the following consequences may be deduced:

1. The accidental colour of a red square, lying upon a white or a black ground, ought to be blackish, if we cast our eyes upon a red coloured surface. 2. If the surface upon which we look at a red square be itself coloured, if it be yellow, for instance, the white paper upon which we afterwards cast our eyes will appear blue, with a green square in it corresponding to the original red square. And, in general, we ought to perceive the accidental colour of the ground on which the square is placed, as well as the square itself. 3. If while we are looking at the little square we change the situation of the eye, so that its image shall occupy a different place on the retina, when we turn our eyes to the white paper we shall see two squares, or at least one unlike the figure of the original one. 4. If the white paper on which we look be farther distant than the little square was, the imaginary square will appear considerably larger than the true one. 5. If while we are looking at the little square, we gradually make the eye approach to it, without altering its situation, the imaginary square will appear with a pale border. These, and many other consequences that might easily be deduced, will be found to take place constantly and accurately, if any one chooses to put them to the test of experiment; and therefore may be considered as a complete confirmation of the theory given above of the cause of accidental colours.

There is another circumstance respecting accidental colours which deserves attention. If we continue looking steadfastly at the little square longer than is necessary, in order to perceive its accidental colour, we shall at last see its border tinged with the accidental colour of the ground on which the square is lying. For instance, if a white square be placed upon blue paper, its border becomes yellow; if upon red paper, it becomes green; and it becomes reddish upon green. In like manner, the border of a yellow square becomes greenish upon a red ground, and that of a red square on a green ground becomes purple.

The cause of this phenomenon seems to depend upon the contraction and extension of the image of the square painted on the retina. We know for certain, that the diameter of the pupil changes during our inspecting the square; at first it becomes less, and afterwards increases. And though we cannot see what passes in the bottom of the eye, we can scarcely doubt that similar movements are going on there, if we attend to the changes

that are continually taking place in the border of our little square; sometimes it is large, sometimes small; at one time it disappears altogether, and the next moment makes its appearance again.

There is another phenomenon connected with accidental colours, which it is not so easy to explain; namely, that if we look at these little squares for a very long time, till the eye is very much fatigued, their accidental colours will appear even after we shut our eyes. The very same thing takes place if we attempt to look at a very luminous object; as the sun, for instance. Professor Scherffer thinks that this may be partly owing to the light which still passes through the eye-lids. That some light passes through the eye-lids is evident, because when we look towards a strong light with our eye-lids shut, we see distinctly their colour, derived from the blood-vessels with which they are filled; and if we pass our finger before our eyes, we see the shadow of the finger though our eye-lids be shut, provided our eyes be turned towards the window. But that this light is not sufficient to explain the phenomenon in question is evident from this circumstance, that the same accidental colours make their appearance though we go immediately into the darkest place. Perhaps we have accounted for the phenomenon elsewhere (See METAPHYSICS, *Encycl.* n^o 54.) We pass over the other conjectures of Professor Scherffer, which are exceedingly ingenious, but not sufficiently supported by facts to be admitted.

COLUMBA NOACHI, *Noah's Dove*, a small constellation in the southern hemisphere, consisting of 10 stars.

COMAR, or KHOMAR, a Zemindar's demesne of land.

COMBUSTION is an operation of nature, which, though of the highest importance, seems not to have attracted much of the attention of philosophers previous to the seventeenth century. Since that period indeed, the labours of Bacon and Boyle, and Hooke and Mayow, together with those of Stahl and Lavoisier, have thrown much light on the subject; as the reader will find by consulting the articles CHEMISTRY both in this Supplement and in the Encyclopædia. The theory of Lavoisier is by far the most rational that has yet been offered to the public, and places its author in the first ranks of philosophy. He corrects the errors of his predecessors, and has advanced before them one very important step; but, as we have elsewhere observed, many new steps are still wanting to render his theory of combustion complete. It explains indeed, in a satisfactory manner, why, during the process of combustion, the burning body gradually wastes away; but it gives no explanation of the constant emission of heat and light, though a circumstance as worthy of attention as the wasting of the body.

The emission of light and heat the French chemists seem indeed to have considered as of no importance; for rather than acknowledge that the theory of their justly admired and ill-fated associate is incomplete, they have chosen to give a new meaning to the word *combustion*; and to make it signify the *combination of a body with oxygen*, whether during that process light and heat be evolved or not. Surely such conduct is unphilosophical; and yet our own chemists, with a servility which ill becomes the countrymen of Bacon and New-

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ton, have, for the most part, acquiesced in this absurd definition of combustion.

From the class of idolaters of the science of the *great nation* must be excepted Dr Thomson, the author of the article CHEMISTRY in this Supplement. Sensible that *combustion*, in the sense usually affixed to that word, denotes a phenomenon very different from many of those which are included under the term in its new acceptation, he acknowledges the theory of Lavoisier to be defective; but influenced by that diffidence which is the inseparable attendant on the spirit of true philosophy, he has not ventured to complete it in the article to which we have referred. He has indeed formed a theory of his own, and submitted it to public discussion; but, with great propriety, gives it no place in his System of the Science, till it shall have undergone the examination of other chemists.

The conductor of this work, however, persuaded that, while gratifying his readers in general, he shall not injure his friend's fame, embraces with pleasure the opportunity afforded him, by a new edition, of laying before them a concise view of this very ingenious theory.

Dr Thomson, then, admitting the truth and accuracy of the Lavoisierian theory as far as it proceeds, divides the bodies which occupy the attention of chemists into, 1. *Combustibles*; 2. *Supporters of combustion*; and, 3. *Incombustibles*.

The COMBUSTIBLES, or those bodies which, in common language, are said to *burn*, may be divided into, 1. *Simple combustibles*; 2. *Compound combustibles*; and, 3. *Combustible oxides*. *Simple combustibles* are, *sulphur*, *phosphorus*, *carbon*, *hydrogen*, and all the *metals*, except perhaps *gold*, *silver*, and *mercury*. *Compound combustibles* consist of compounds formed by the simple combustibles uniting together two and two; and *combustible oxides* are composed of one or more simple combustibles combined with a dose of *oxygen*. These oxides may be arranged under two heads: viz. those which containing only a *single base* combined with oxygen, may therefore be termed *simple combustible oxides*; and those which containing *more than one base*, may therefore be termed *compound combustible oxides*. The simple combustible oxides are only four in number; namely, *oxide of sulphur*, *oxide of phosphorus*, *charcoal*, and *carbonic oxide gas*. All the simple combustible oxides are by combustion converted into *acids*. The compound combustible oxides include by far the greater number of combustible bodies; for almost all the animal and vegetable substances belong to them, and the double base is usually *carbon* and *hydrogen*.

The SUPPORTERS of combustion are a set of bodies which are not of themselves, strictly speaking, capable of undergoing combustion, but which are absolutely necessary for the process. All the supporters known at present are six; viz. 1. *Oxygen gas*; 2. *Air*; 3. *Gaseous oxide of azot*; 4. *Nitrous gas*; 5. *Nitric acid*; and, 6. *Oxy-muriatic acid*. There are other substances, to be mentioned afterwards, to which the author gives the name of *partial supporters*; but all supporters contain one common principle, namely *oxygen*.

The INCOMBUSTIBLE BODIES are neither capable of undergoing combustion themselves, nor of supporting the combustion of bodies that are. Of course, they are not immediately connected with combustion; but they are noticed here, because some of the alkalies and

earths, which belong to this class, possess certain properties in common with combustibles, and are capable of exhibiting phenomena somewhat analogous to combustion; phenomena which the author describes under the title of *semi-combustion*.

From the preceding observations it is obvious, that, in every case of combustion, there must be present a *combustible* and a *supporter*; and Lavoisier ascertained beyond a doubt, that, during the process, the combustible always unites with the oxygen of the supporter. This new compound our author calls a *product of combustion*; and maintains that every such product is either *water*, or an *acid*, or a *metallic oxide*. He admits, indeed, that other bodies sometimes make their appearance during combustion; but affirms that these, upon examination, will be found neither to be products, nor to have undergone combustion.

But though the combination of the combustible with oxygen be a constant part of combustion, yet the facility with which combustibles burn is not in proportion to their apparent affinity for that gas. Phosphorus, for instance, burns more readily than charcoal; yet charcoal is capable of abstracting oxygen from phosphorus. The combustible oxides take fire more readily than some of the simple combustibles. Thus, charcoal burns more easily than carbon or diamond; and alcohol, ether, and oils, which are all compound combustible oxides, are exceedingly combustible; whereas the metals, which are simple combustibles, do not burn, when air is the supporter, but at a very high temperature. This facility of burning combustible oxides is probably owing to the weak affinity by which their particles are united; and to the same cause, viz. the inferiority of the cohesion of heterogeneous particles, is to be attributed the fact, that some of the *compound supporters* occasion combustion in circumstances when the combustibles would not be acted on by *simple supporters*.

None of the *products* of combustion are themselves combustible, in the usual and proper acceptation of that word. This, however, is not owing to their being saturated with oxygen, for several of them are capable of combining with an additional dose of it; but during this new combination no caloric nor light is ever emitted, and the compound formed differs essentially from a mere *product* of combustion, being by the additional dose of oxygen converted into a *supporter*.

When the *supporters*, thus formed by the combination of oxygen with *products*, are made to support combustion, they do not lose all their oxygen, but only the *additional dose* which constituted them supporters. Of course they are again reduced to their original state of products of combustion; and as they owe their properties as supporters, not to the whole of the oxygen which they contain, but to the additional dose, the author calls them *partial supporters*.

All the partial supporters with which we are acquainted contain a metallic basis; for metallic oxides are the only products at present known capable of combining with an additional dose of oxygen. The following oxides, which are products of combustion, combined each with an additional dose of oxygen, are *partial supporters*: 1. Red oxide of iron; 2. Yellow oxide of gold; 3. White oxide of silver; 4. Red oxide of mercury; 5. Arsenic acid; 6. Red and brown oxides

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of lead; 7. Black oxide of manganese; 8. Acidulous oxide of antimony? 9. White oxide of tin.

Thus it appears that several of the products of combustion are capable of combining with oxygen; and hence it follows that the incombuftibility of products is not owing to their want of affinity for oxygen, but to some other caufe.

Though no mere product of combustion is capable of supporting combustion, this is not occasioned by any want of affinity for combuftible bodies; for feveral of thefe products are capable of combining with an additional dofe of their bafes. By this combination, however, they lofe their properties as products, and are converted into *combustibles*; whence it follows that the procefs muft differ essentially from that of combustion. Thus fulphuric acid, a product of combustion, by combining with an additional dofe of fulphur or its oxide, is converted into *fulphurous acid*; a fubftance which, from many of its properties, Dr Thomson concludes to be *combustible*. Thus alfo phosphoric acid, a product of combustion, is capable of combining with phosphorated hydrogen, and forming *phosphorous acid*, a combuftible body. When this laft acid is heated in contact with a fupporter, it undergoes combustion; but it is only the additional dofe of the combuftible which burns, and the whole is converted into phosphoric acid. Hence we fee that it is not the whole bafis of thefe compounds that is combuftible, but merely the additional dofe; and therefore the compounds themfelves may be termed *partial combustibles*, to indicate, that part only of the bafe is capable of undergoing combustion. Now, fince the products of combustion are capable of combining with oxygen, but never exhibit the phenomena of combustion, except when they are in the ftate of partial combustibles, combuftible bodies muft contain fome principle, which they lofe during combustion, and to which they owe their combuftibility; for after they have loft it, they unite to oxygen without exhibiting the phenomena of combustion.

Though the products of combustion are not capable of supporting combustion, they not unfrequently part with their oxygen juft as fupporters do, give it out to combuftibles, and convert them into products; but during this procefs no heat nor light is ever evolved. Water, for inftance, gives out its oxygen to iron, and converts it into *black oxide*, a product; and fulphuric acid gives out its oxygen to phosphorus, and converts it into phosphoric acid. Thus we fee that the oxygen of products is capable of converting combuftibles into products, juft as the oxygen of fupporters; but during the combination of the laft only are heat and light emitted. The oxygen of fupporters, then, contains fomething which the oxygen of products wants.

Whenever the whole of the oxygen is abftacted from products, the combuftibility of their bafe is reftored as completely as before combustion; but no fubftance is capable of abftacting the whole of oxygen, except a *combustible* or a *partial combustible*; and when this is done, the combuftible or partial combuftible lofes its own combuftibility by the procefs, and is converted into a product.

From thefe facts, which have been all eftablifhed by Stahl, Lavoifier, and our author, it follows that the products of combustion may be formed without actual

combustion; but in thefe cafes a *new combustibile* is always evolved. The procefs is merely an interchange of combuftibility; for the combuftible is converted into a product only by means of a product. Both the oxygen and the bafe of the product having undergone combustion, have loft fomething which is effential to combustion. The procefs is merely a double decomposition. The product yields its oxygen to the combuftible, while, at the fame time, the combuftible gives out fomething to the bafe of the product. The combuftibility of that bafe, then, is reftored by the lofs of its oxygen, and by the reftoration of fomething which it receives from the other combuftible thus converted into a product.

No *fupporter* can be produced by combustion, or by any equivalent procefs. Now as all the fupporters, except oxygen gas, confift of oxygen combined with a bafe, it follows as a confequence, that oxygen may combine with a bafe, without lofing that ingredient, whatever it is, which gives occafion to combustion. The mere act of combination of oxygen with a bafe, therefore, is by no means the fame with combustion.

Several of the fupporters and partial fupporters are capable of combining with combuftibles, without undergoing decomposition, or exhibiting the phenomena of combustion. In this manner the yellow oxide of gold, and the white oxide of filver, combine with ammonia; the red oxide of mercury with oxalic acid; and oxy-muriatic acid with ammonia. Thus alfo nitre and oxy-muriat of potafh may be combined, or at leaft intimately mixed with feveral combuftible bodies, as in gunpowder, &c. In all thefe compounds the oxygen of the fupporter retains each the ingredients proper to itfelf, which render them fufceptible of combustion; and hence the compound is ftill combuftible. They burn indeed with amazing facility, not only when heated, but when triturated or ftuck fmartly with a hammer; and have received, in confequence, the name of *detonating* or *fulminating* bodies.

Such are the properties of the combuftibles, the fupporters, and the products; and fuch the phenomena which they exhibit when made to act upon each other. If we compare together the *fupporters* and the *products*, we fhall find that they refemble each other in feveral refpects. Both of them contain oxygen as an effential part; both are capable of converting combuftibles into products; and of both feveral combine with combuftibles and with additional dofes of oxygen. But they differ widely from each other in the phenomena which accompany their action on combuftibles. The fupporters convert thefe bodies into products; and at the fame time combustion, or the emission of light and heat, takes place; whereas the products convert combuftibles into products without any fuch emission. Now as the ultimate change produced upon combuftibles by both thefe fetts of bodies is the fame, and as the fubftance which combines with the combuftibles is in both cafes the fame, namely oxygen, we muft conclude that this oxygen in the fupporters contains fomething which the oxygen of the products wants; fomething which feparates during the paffage of the oxygen from the fupporter to the combuftible, and occasions the combustion, or emission of fire, which accompanies this paffage. The oxygen of fupporters, then, contains fome ingredient

Combustion.

Combustion. Combustion.
 dient which the oxygen of products wants. Many circumstances concur to render it probable that this ingredient is CALORIC.

The *combustibles* and the *products* also resemble each other in several respects. Both of them contain the same or a similar base; both frequently combine with combustibles, and likewise with oxygen: but they differ essentially in the phenomena which accompany their combination with oxygen. In the one case, *fire* is emitted; in the other, not. If we recollect that no substance but a combustible is capable of restoring combustibility to the base of a product, and that at its doing so, it always loses its own combustibility; and if we recollect farther, that the base of the product does not exhibit the phenomenon of combustion even when it combines with oxygen—we cannot avoid concluding, that all combustibles contain an ingredient which they lose when converted into products, and that this loss contributes to the fire which makes its appearance during the conversion. Many circumstances concur to render it probable that this ingredient is LIGHT.

If we suppose that the oxygen of *supporters* contains *caloric* as an essential ingredient, and that *light* is a component part of all *combustibles*, the phenomena of combustion, numerous and intricate as they are, admit of an easy and obvious explanation. The component parts of the oxygen of supporters are two; namely, 1. A *base*; and, 2. *Caloric*. The component parts of combustibles are likewise two; namely, 1. A *base*; and, 2. *Light*. During combustion the base of the oxygen combines with the base of the combustible, and forms the product; while at the same time the caloric of the oxygen combines with the light of the combustible, and the compound flies off in the form of fire. Thus combustion is a double decomposition; the oxygen and combustible divide themselves each into two portions, which combine in pairs; the one compound is the *product*, and the other the *fire*, which escapes. Hence the reason that the oxygen of products is unfit for combustion: It wants its *caloric*. Hence the reason that combustion does not take place when oxygen combines with products, or with the base of supporters: These bodies contain no *light*. The caloric of the oxygen of course is not separated, and no *fire* appears. Hence also the reason why a combustible alone can restore combustibility to the base of a product. In all such cases a double decomposition takes place. The oxygen of the product combines with the base of the combustible, while the light of the combustible combines with the base of the product.”

Such is the theory of Dr Thomson, proposed to the public* under the humble title of *Remarks on Combustion*. As the author completely establishes the facts on which his reasoning rests, we can conceive to it but one plausible objection. Why is not the caloric of the oxygen separated when that gas combines with bodies destitute of light? That there is caloric emitted on many occasions, when no light *appears* with it, is incontrovertible; but perhaps the matter of light is chemically combined with all bodies which emit heat, though it never flies off but when the heat is great. If this be a fact, and it is not improbable, the theory before us seems to be established; for it not only completes the theory of Lavoisier, but affords an *easy solution* to some phe-

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nomena which have been thought inconsistent with that theory.

In the year 1793, the associated Dutch chemists drew the attention of philosophers to a curious phenomenon which accompanies the formation of some of the sulphurets. When eight parts of copper, iron, lead, tin, or zinc filings, and three parts of flowers of sulphur, are mixed together in a glass receiver, and the vessel placed upon burning coals, the mixture melts, a kind of explosion takes place, it becomes suddenly red hot, and a glow, like that of a piece of red hot charcoal fanned with bellows, rapidly pervades the whole. When this disappears, the mixture is found in the state of solid sulphuret of copper, or iron, &c. The experiment succeeds whether the vessel be filled with air, or with azotic or hydrogen gas, or even with water or mercury. What is singular in this experiment is the glowing *red heat*, or the emission of fire, which accompanies the combination of the sulphur and metal. This emission being the same which takes place during combustion, the process has been considered as a combustion, and stated as such, by the German chemists, as an objection to Lavoisier's theory. But our author shews that no objection can be urged from this experiment against the truth of that theory as far as it goes; and that all the phenomena are fully explained by the additions which he has made to it. Thus, we have only to recollect, 1. That the sulphur in a melted state, and therefore contains caloric as an ingredient; 2. That the metals which produce the phenomenon contain light as an essential ingredient; and, 3. That the sulphuret produced is always in a solid state—and the explanation is simple and obvious. The *sulphur* combines with the *base* of the metal, while the *caloric*, to which the sulphur owed its fluidity, combines with the *light* of the metal, and the compound flies off under the form of *fire*.

Thus the process is exactly the same with combustion, excepting what regards the product. The melted sulphur acts the part of the *supporter*, while the metal occupies the place of the *combustible*. The first furnishes caloric, the second light, while the bases of both combine together. Hence we see that the base of sulphurets (and the same thing holds of some phosphurets) resembles the base of products in being destitute of light, the formation of these bodies exhibiting the separation of fire like *combustion*; but the product, differing from a product of combustion in being destitute of oxygen, our author proposes to distinguish the process by the title of *semi-combustion*, to indicate that it possesses one half of the characteristic marks of combustion, but is destitute of the other half.

COMPASS, or MARINER'S STEERING COMPASS, is an instrument of so great value, that every improvement of it, proposed by men of science or of experience, is entitled to notice. We shall therefore lay before our readers some observations on the defects of the compass in common use, which have fallen into our hands since the article in the Encyclopædia was published. The first is by Captain O'Brien Drury of the royal navy, and relates entirely to the needle.

“Experience (says this officer) shews us, that the needle of a compass, as well as all other magnets, whether artificial or real, perpetually loses something of its magnetic

* *Nicholson's Journal*, vol. ii. Second series.

Compass. magnetic powers, which often produces a difference exceeding a point; and I am well convinced that the great errors in ship-reckonings proceed more frequently from the incorrectness of the compass than from any other cause.

“Steel cannot be too highly tempered for the needle of a sea-compass, as the more it is hardened the more permanent is the magnetism it receives; but, to preserve the magnetism, and consequently the polarity of the needle, I recommend to have the needle cased with thin, well-polished, soft iron; or else to have it armed at the poles with a bit of soft iron. I have found, from many experiments, that the cased needle preserved its magnetism in a much more perfect degree than the needle not cased; and I have sometimes thought that the magnetic power of the cased needle had increased, while the magnetic power of the uncased and unarmed needle always loses of its polarity.”

This is not an opinion taken up at random, but is the result of what appears to have been a fair and judicious experiment; for our author placed a cased needle, an armed needle, and one without either case or armour, in a room for three months; each having at that time precisely the same direction, and nearly the same degree of force. At the expiration of the three months, he found that the cased needle and the armed needle had not in the least changed their direction; but the other had changed two degrees, and had lost very considerable of its magnetic power. If there was any change in either of the other needles, it was too inconspicuous to be perceived.

These observations seem to be new, and may tend to the improvement of the compass. But it is not with respect to the needle only that this instrument is defective. Mr Bernard Romans of Pensacola well observes, that, on another account, the heaviest brass compasses now in use are by no means to be relied on in a hollow or high sea. This is owing to the box hanging in two brass rings, confining it to only two motions, both vertical and at right angles with each other; by which confinement of the box, upon any concussion, more especially sudden ones, the card is always put into too much agitation, and, before it can well recover itself, another jerk prevents its pointing to the pole; nor is it an extraordinary thing to see the card unshipped by the violence of the ship's pitching.

All these inconveniences are remedied to the full by giving the box a vertical motion at every degree and minute of the circle, and compounding these motions with a horizontal one of the box as well as of the card. By this unconfined disposition of the box, the effects of the jerks on the card are avoided, and it will always very steadily point to the pole. “Experience (says our author) has taught me, that the card not only is not in the smallest degree affected by the hollow sea, but that, in all the violent shocks and whirlings the box can receive, the card lies as still as if in a room unaffected by the least motion.

“Lately a compass was invented and made in Holland, which has all these motions. It is of the size of the common brass compasses; the bottom of the brass box, instead of being like a bowl, must be raised into a hollow cone, like the bottom of a common glass bottle; the vertex of the cone must be raised so high as to leave but one inch between the card and the glass; the box

must be of the ordinary depth, and a quantity of lead Compass. must be poured in the bottom of the box, round the base of the cone; this secures it on the stile whereon it traverses.

“This stile is firmly fixed in the centre of a square wooden box, like the common compass, except that it requires a thicker bottom. The stile must be of brass, about six inches long, round, and of the thickness of one-third of an inch; its head blunt, like the head of a sewing-thimble, but of a good polish: the stile must stand perpendicular. The inner vertex of the cone must also be well polished; the vertical part of the cone ought to be thick enough to allow of a well-polished cavity, sufficient to admit a short stile, proceeding from the centre of the card whereon it traverses. The compass I saw was so constructed; but I see no reason why the stile might not proceed from the centre of the vertex of the cone, and so be received by the card the common way. The needle must be a magnetic bar, blunt at each end; the glass and cover are put on in the common way.”

A compass of this kind was submitted to our author's examination by the captain of a sloop of war, who assured him, that in a hard gale, which lasted some days, there was no other compass of the smallest service. Mr Romans was satisfied that the officer did not praise the apparatus more than it deserved; and we feel ourselves strongly inclined to be of the same opinion.

It must not be concealed, however, that the ingenious Mr Nicholson seems to think very differently of all such contrivances. In a paper published in the ninth number of his valuable Journal, he labours to prove, that the compass is very little disturbed by tilting the box on one side, but very much by sudden horizontal changes of place; that a scientific provision against the latter is therefore the chief requisite in a well made instrument of this kind; and that no other provision is requisite or can easily be obtained, than good workmanship according to the common construction, and a proper adjustment of the weight with regard to the centres or axes of suspension. The same author is of opinion, that it would greatly improve the compass to make the needle flat and thin, and to suspend it, not, as is most commonly done, with its flat side, but with its edge uppermost; for it being a well-known fact, that soft steel loses its magnetism sooner than hard, it is obvious, that unless both sides of a needle be equally hard (which is almost impossible if they be distant from each other), the magnetic power will, in process of time, deviate towards the harder side.

The Chinese COMPASS has some advantages over the European compass, from which it differs with respect to the length of the needle, and the manner in which it is suspended. In the compass of China, the magnetic needle is seldom above an inch in length, and is less than a line in thickness. It is poised with great nicety, and is remarkably sensible, or, in other words, points steadily towards the same portion of the heavens. This steadiness is accomplished by the following contrivance: “A piece of thin copper is strapped round the centre of the needle. This copper is rivetted by its edges to the upper part of a small hemispherical cup, of the same metal, turned downwards. The cup so inverted serves as a socket to receive a steel pivot rising from a cavity made into a round piece of light wood or cork, which thus

Compass,
Complement.

thus forms the compass-box. The surfaces of the socket and pivot, intended to meet each other, are perfectly polished, to avoid, as much as possible, all friction. The cup has a proportionably broad margin, which, beside adding to its weight, tends, from its horizontal position, to keep the centre of gravity, in all situations of the compass, nearly in coincidence with the centre of suspension. The cavity, in which the needle is thus suspended, is in form circular, and is little more than sufficient to remove the needle, cup, and pivot. Over this cavity is placed a thin piece of transparent talc, which prevents the needle from being affected by any motion of the external air; but permits the apparent motion of the former to be easily observed. The small and short needle of the Chinese has a material advantage over those of the usual size in Europe, with regard to the inclination or dip towards the horizon; which, in the latter, requires that one extremity of the needle should be made so much heavier than the other as will counteract the magnetic attraction. This being different in different parts of the world, the needle can only be accurately true at the place for which it had been constructed. But in short and light needles, suspended after the Chinese manner, the weight below the point of suspension is more than sufficient to overcome the magnetic power of the dip or inclination in all situations of the globe; and therefore such needles will never deviate from their horizontal position."

COMPLEMENT, in general, is what is wanting, or necessary, to complete some certain quantity or thing.

Arithmetical COMPLEMENT, is what a number or logarithm wants of unity or 1 with some number of cyphers. It is best found by beginning at the left hand side, and subtracting every figure from 9, except the last, or right hand figure, which must be subtracted from 10. So, the arithmetical comp. of the log. 9.5329714, by subtracting from 9's, &c. is 0.4670286.

The arithmetical complements are much used in operations by logarithms, to change subtractions into additions, which are more conveniently performed, especially when there are more than one of them in the operation.

COMPLEMENT, in astronomy, is used for the distance of a star from the zenith; or the arc contained between the zenith and the place of a star which is above the horizon. It is the same as the complement of the altitude, or co-altitude, or the zenith distance.

COMPLEMENT of the Course, in navigation, is the quantity which the course wants of 90°, or 8 points, viz. a quarter of the compass.

COMPLEMENT of the Curtain, in fortification, is that part of the anterior side of the curtain which makes the demigorge.

COMPLEMENT of the Line of Defence, is the remainder of that line, after the angle of the flank is taken away.

COMPLEMENTS of a Parallelogram, or in a Parallelogram, are the two lesser parallelograms, made by drawing two right lines parallel to each side of the given parallelogram, through the same point in the diagonal.

COMPLEMENT of Life, a term much used, in the doctrine of life annuities, by De Moivre; and, according to him, it denotes the number of years which a given life wants of 86, this being the age which he considered as the utmost probable extent of life. So 56 is the complement of 30, and 30 is the complement of 56.

COMPOSITION OF PROPORTION, according to the 15th definition of the 5th book of Euclid's Elements, is when, of four proportionals, the sum of the first and second is to the second, as the sum of the third and fourth is to the fourth.

COMPOSITION of Ratios, is the adding of ratios together: which is performed by multiplying together their corresponding terms, viz. the antecedents together, and the consequents together, for the antecedent and consequent of the compound ratio; like as the addition of logarithms is the same thing as the multiplication of their corresponding numbers. Or, if the terms of the ratios be placed fraction-wise, then the addition or composition of the ratios is performed by multiplying the fractions together.

COMPOUND INTEREST. See **ALGEBRA**, *Encycl.* and *Compound INTEREST* in this *Supplement*.

CONCEPTION, a city of Chili in South America, was visited in 1786 by the celebrated, though unfortunate, navigator La Perouse, who gives an account of some particulars relating to it very different from what we have given of it under the article **CONCEPTION**, *Encycl.* So far are the Spaniards from living in security with respect to the Indians, that, according to him, they are under continual alarms of being attacked by those bold and enterprising savages. "The Indians of Chili (says he) are no longer those Americans who were inspired with terror by European arms. The increase of horses, which are dispersed through the interior of the immense deserts of America, and that of oxen and sheep, which has also been very great, have converted these people into a nation of Arabs, in every thing resembling those who inhabit the deserts of Arabia. Constantly on horseback, they consider an excursion of two hundred leagues as a very short journey. They march accompanied by their flocks; feed upon their flesh and milk, and sometimes upon their blood; and cover themselves with their skins, of which they make helmets, cuirasses, and bucklers. All their old customs are laid aside. They no longer feed upon the same fruits, nor wear the same dress; but have a more striking resemblance to the Tartars, or to the inhabitants of the banks of the Red Sea, than to their ancestors, who lived two centuries ago. So decisive an influence has the introduction of two domestic animals had upon the manners of that once timid people. It is easy to conceive what formidable enemies they must now be to the Spaniards; for supposing them defeated in battle, how is it possible to follow them in such long excursions? How is it possible to prevent assemblages, which bring together in a single point nations scattered over 400 leagues of country, and thus form armies of 30,000 men?"

Of these people M. Rollin, surgeon-major of the frigate *la Buffale*, gives the following physiological particulars: "They are, in general (says he), of lower stature, and less robust, than Frenchmen, though they endure with great courage the fatigues of war and all its attendant privations. There is a great sameness in the physiognomy of most individuals. The face is larger and rounder than that of Europeans. The features are more strongly marked. The eyes are small, dull, black, and deeply seated. The forehead is low; the eyebrows black and shaggy; the nose short and flattened; the cheek-bones high; the lips thick; the mouth wide;

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Conception and the chin diminutive. The women are short, ill-made, and with disgusting countenances. Both men and women bore their nose and ears, which they adorn with glass or mother-of-pearl trinkets. The colour of their skin is a reddish brown: That of their nails is similar, but not so deep. The hair of both is black, coarse, and very thick. The men have little beard; but their arm-pits and parts of sex are well furnished with hair, which parts, in most of the women, have none."

The military governor of Conception, who was an Irishman, returned, while M. de la Perouse was there, from the frontiers of the Spanish settlements, where he had just concluded a glorious peace with the Indians. This peace was highly necessary to the people of his government, whose distant habitations were exposed to the inroads of savage cavalry, whose practice it is to massacre the men and children, and to make the women prisoners. This amiable man, whose name was *Higuins* (probably *Higgins*), had succeeded in gaining the good-will of these savages, and thereby adopted the most signal service to the nation that had adopted him. For while the Indians and Spaniards are at variance, an alliance with the former by any of the maritime powers of Europe would become so formidable to the latter, as to induce them, for fear of their lives, to abandon their settlements in Chili, and retire to Peru. This was clearly seen by *Monneron* the engineer on the expedition, who, with the true spirit of a Frenchman, pointed out to his government the method of wresting from its most faithful ally one of the most valuable provinces of the Spanish empire.

La Perouse describes the common people of Conception as much addicted to thieving, and the women as exceedingly easy of access. "They are a degenerated and mongrel race (says he); but the inhabitants of the first class, the true bred Spaniards, are polite and obliging in the extreme. The bishop was a man of great sense, of agreeable manners, and of a charity of which the Spanish prelates afford frequent examples." He was a Creole, and had never been in Europe. Of the monks our author gives a very different character. "The misfortune (says he) of having nothing to do, the want of family ties, the profession of celibacy, without being separated from the world, and their living in the convenient retirement of their cells, has rendered, and could not fail to render, them the greatest profligates in America. Their effrontery is inconceivable. I have seen some of them stay till midnight at a ball; aloof, indeed, from the good company, and seated among the servants. These same monks gave our young men more exact information than they could get elsewhere, concerning places with which priests ought to have been acquainted only in order to interdict the entrance."

M. de la Perouse represents that part of Chili, which is called *the Bishopric of Conception*, as one of the most fertile countries in the universe. Corn yields sixty to one; the vineyards are equally productive; and the plains are covered with innumerable flocks, which, tho' left to themselves, multiply beyond all imagination. Yet this colony is far from making the progress that might be expected from a situation so favourable to an increase of population. The influence of the government incessantly counteracts the climate and the soil. Prohibitory regulations exist from one end of Chili to the

other; and this kingdom, of which the productions, if Condorcet carried to their highest pitch, would feed the half of Europe; of which the wool would suffice for the manufactures of Great Britain and France, even when manufactures flourished in the latter country; and of which the cattle, if salted down, would produce an immense revenue—is entirely destitute of commerce, and its inhabitants sunk in sloth and indolence. Unless, therefore, Spain change its system entirely, Chili will never reach that pitch of prosperity which might be expected from its situation and fertility. For the latitude and longitude of Conception, see *Encycl.*

CONDORCET (Jean-Antoine Nicolas Caritat de), was born at Ribemont in Picardy, the 17th of September 1743, of a noble and very ancient family. At the age of 15 he was sent to study philosophy at the college of Navarre, and had the good fortune to fall into the hands of an able professor, who has since distinguished himself by his geometrical works. The young Condorcet had no relish for the business of the first course, for the quibbles of ontology and pneumatology, and all the wretched appendages of school metaphysics: But in the following year, his studies, being directed to the mathematical and physical sciences, were entirely congenial to his taste; and though there were upwards of 120 scholars, he distinguished himself above them all. At Easter he held a public thesis, at which Clairaut, D'Alembert, and Fontaine, assisted. He now returned home, but continued to cultivate geometry. To enjoy more opportunities of improvement, he removed in 1762 to Paris; where he attended the chemical course of Macquer and Beaumé, and frequented the literary societies which D'Alembert had formed at the house of Mademoiselle de Lespinaffe.

In 1765, when only 22 years old, he published a work on the Integral Calculus, which discovered vast extent and originality of views. Condorcet was already numbered with the foremost mathematicians in Europe. "There was not (says La Lande) above ten of that class; one at Petersburg, one at Berlin, one at Basle, one at Milan, and five or six at Paris; England, which had set such an illustrious example, no longer produced a single geometer that could rank with the former." It is mortifying to us to confess that this remark is but too much founded in truth. We doubt not but there are in Great Britain at present mathematicians equal in profundity and address to any who have existed since the illustrious Newton; but these men are not known to the learned of Europe, because they keep their science to themselves. They have no encouragement, from the taste of the nation, to publish any thing in those higher departments of geometry which have so long occupied the attention of the mathematicians on the continent.

In 1767 Condorcet published his solution of the problem of three bodies; and in the following year, the first part of his *Analytical Essays*; in which he entered very profoundly into those arduous questions. He was received into the academy on the 8th of March 1769; and from that time till 1773 he enriched their annual volumes with memoirs on infinite series, on partial and finite differences on equations of condition, and on other objects of importance in the higher calculus. It must be regretted, that he indulged speculation perhaps to excess; the methods that he proposes for integration

Condorcet gratation are sometimes of a nature so extremely general, as to refuse to be accommodated to practice. Prosecuting those researches for several years longer, he composed an ample Treatise on the Integral Calculus, in five parts, comprising the doctrines and their application. It was afterwards copied out for the press in 1785 by Keralio, formerly governor to the Infant of Parma. Only 128 pages were printed; but the manuscript still exists; as does that of an elementary Treatise on Arithmetic. It is to be hoped that both of these will yet be given to the public.

His attention was not, however, entirely absorbed in those recondite studies. He published about this time an anonymous pamphlet, intitled *A Letter to a Theologian*; in which he replied with keen satire to the attacks made by the author of the *Three Centuries of Literature* against the philosophical sect. "But (subjoins the prudent La Lande) he pushed the matter somewhat too far; for, admitting the justness of his system, it was more prudent to confine within the circle of the initiated those truths which are dangerous for the multitude, who cannot replace by sound principles what they would lose of fear, of consolation, and of hope." Condorcet was now leagued with the atheists; and *La Lande*, who wishes well to the same sect, censures not his principles, but only regrets his rashness. He was indeed, as Mr Burke observed, a fanatic atheist and furious democratic republican.

On the 10th of June 1773 he was made secretary of the academy of sciences; and that important trust he discharged through the rest of his life with great ability and uncommon reputation. The duties of his office required him to write the lives of the deceased academicians, which he performed with diligence, judgment, and universal applause: And what species of composition is capable of being rendered so extensively useful as biography? In the most insinuating form it conveys instruction; and, bestowing vitality and action on the rules of conduct and on the lessons of virtue, it fires the breast with the noblest emulation. The life of a philosopher must also include a portion of the history of science. We there trace the successive steps which led to discoveries, and learn to estimate the value of those acquisitions by the efforts that were made, and the obstacles that were surmounted. The literati of France have long excelled in the composition of *Eloges*: but those of Condorcet are of a very superior cast. Replete with information and genuine science, they maintain a dignified impartiality, and display vigour of imagination, with boldness and energy of style. The intrepidity (say his Panegyrists) with which he uttered the sentiments of truth and of freedom, could not have been expected from the mouth of an academician under an absolute monarchy. It could not, indeed, till the present eventful age, have been expected under any government whatever; for what he called the sentiments of truth were the dogmas of debasing irreligion, which would not have been permitted in the far-famed republics of Greece and Rome; and what he dignified with the appellation of the principles of freedom, experience has shown to have been the immediate source of anarchy, out of which has sprung a despotism, the heaviest under which any people have groaned since the creation of the world.

Besides the eloges, which properly belonged to his province, Condorcet published in a separate volume

the lives of those *savants*, who, having died before the renewal of the academy in 1699, did not fall in with the plan of Fontenelle. The suppression of the history of the academy, or the regular abstracts of the printed memoirs, which he effected in 1783, afforded him more leisure. In 1787 appeared, yet without a name, his account of Turgot; an inestimable piece, which, in developing the beneficial views of a virtuous and enlightened minister, exhibits the neatest abstract of the principles of political economy that is extant in any language. Nearly about the same time he composed that elegant life which is prefixed to the splendid edition of the works of Voltaire. Condorcet had been elected member of the *Academie Française* in 1782; and his reputation as a fine writer was so well established, that bookfellers were solicitous to cover their undertakings with the sanction of his name. He promised an additional volume to the translation of Euler's Letters to a German Princess; but it was never finished. The part which was printed, amounting to only 112 pages, contains the elements of the calculation of probabilities, and a curious plan of a dictionary, in which objects should be arranged by their qualities merely. A new translation of Smith's celebrated *Wealth of Nations* was likewise announced with the notes of Condorcet, tho' he was never heartily engaged about it. On equally slight grounds, his name was lent to the *Bibliotheque de l'Homme Public*; and the facility of his temper laid him but too open, at this period, to such disingenuous arts. Indeed disingenuous arts seem to be the natural offspring of the present philosophy of France; for the tricks played by Voltaire to his bookfellers, which are well known, would in this country have sunk into disgrace the greatest genius that ever lived; and the attempt of Diderot to cheat the late empress of Russia, by selling to her, at an immense price, a library, which he pretended to be one of the most valuable in Europe, when he possessed not perhaps one hundred volumes, was disingenuity ingrafted on impudence. But to return from this short digression.

These literary pursuits did not entirely seduce Condorcet from more profound studies. At the instigation of Turgot, he sought to apply analysis to questions of politics and morality. His first Memoir on Probabilities was read to the academy in 1781. He afterwards extended his researches to the consideration of elections, sales, and successions; and digesting those remarks and calculations into a systematic shape, he published in 1785 a quarto volume, containing the elements of a new and important science.

It is easy to conceive the interest that Condorcet would take in the success of the revolution. Aware of the prodigious influence of newspapers, he contributed largely to the *Journal de Paris*, and the *Chronique*, which acquired great celebrity from the elegance of his pen; and not very long before his death, he began, in concert with the famous Sieyes, a Journal of Social Instruction. In 1791 he wrote a pamphlet in favour of republican government, which procured him a seat in the Legislative Assembly, and the academy permitted him still to retain the office of secretary. He drew up a manifesto on the subject of the war menaced by the crowned heads; and a very ample report on public instruction, which has in part been lately adopted by the councils of France. He was an early member of the

Condorcet. Jacobin club, that active instrument of the revolution: but perceiving the progressive ferocity of its measures, he forsook it in March 1792.

On the 13th of August, when the king was conducted to the temple, Condorcet was named by the Assembly to draw up a justificatory memorial addressed to all Europe. At the dissolution of that Assembly, he was chosen deputy to the National Convention, and for some time acted a distinguished part in its deliberations. He was at the head of the committee appointed to prepare the plan of a republican constitution. But, in the meanwhile, the faction of the Mountain, with a peculiar energy of character, was rapidly acquiring strength. The report of the committee was coldly received—was even treated with contempt; and, on the 31st of May 1793, Robespierre completely triumphed.

During the contest between the Mountain and the Brissotines, Condorcet maintained a cautious silence. For eight months he hardly spoke in the Convention; and seems to have been singularly wary in not risking an opinion on any party question. At length he was so far roused by the indignities which the legislative body daily endured, that he proposed the dissolution of the Convention, and the calling of a new one. This probably exasperated the Mountain to such an excess, that in a subsequent insurrection his printing-office was destroyed. He was not, however, included in the list of proscribed deputies; nor was he one of the members who signed the famous protest against the proceedings on the 31st of May. See REVOLUTION (*Encycl.*), n^o 159.

But though he could conquer every sentiment of friendship, and stifle every indignant sensation at the destruction of his party, his vanity as an author propelled him to a fatal exertion. When the constitution of 1793 was accepted, he published *An Address to all French Citizens*; reprobating the extreme rapidity and want of consideration with which it had been framed and accepted, and detailing the numerous acts of violence by which the prevailing party in the Convention had established their influence. This rash act placed him in the power of the Mountain: Chabot denounced the publication, and moved for a decree of accusation against Condorcet; which was immediately granted.

He escaped from the arrest, and concealed himself nine months in the house of a woman in Paris, who, though she knew him only by name, had the generosity to risk her life, and sustain all the inconveniences arising from her harbouring such a guest. At length a domiciliary visit was threatened, and he was obliged to quit his asylum. He had the good fortune, though unprovided with a passport or civic card, to escape through the barrier; when he went to the country-house of a friend on the plain of Mont-Rouge. Unfortunately his friend was at Paris, and not expected to return in less than three days; during which the fugitive was obliged to wander about, exposed to hunger, cold, suspense, and the pain arising from a wound in his foot. At length his friend returned into the country, and found him; but considering it dangerous to take him to his house in the day-time, requested him to wait till night, when he would receive and conceal him. Condorcet, on that day which his friend had fixed as the end of his miseries, forgot the dictates of prudence, and went to an inn at Chemars, where he ordered an

amelette. His squalid appearance, dirty cap, torn clothes, leanness, and voracity, fixed the attention of a municipal officer, who asked him whence he came, whither he was going, and if he had a passport? His confusion at these interrogatories betrayed him, and he was instantly apprehended. He was confined that night in a dungeon, and in the morning was found dead. He always carried about him a dose of poison, with which he terminated his life, to avoid a trial before the revolutionary tribunal, and shun the gradual approach of inevitable destruction.

Thus miserably perished a philosopher, whose "genius (says Madame Roland) was equal to the comprehension of the vastest subjects; but he had no other characteristic besides fear. It may be said of his understanding, combined with his person, that it was a fine essence absorbed in cotton. No one could say of him, that in a feeble body he displayed great courage; for his heart and his constitution were equally weak. After having deduced a principle, or demonstrated a fact, in the Assembly, he would give a vote decidedly opposite; overawed by the thunder of the tribunes, armed with insults, and prodigal of threats."

It was during the period of his concealment at Paris, uncertain of a day's existence, that he wrote his Sketch of the Progress of the Human Mind; a production which undoubtedly displays genius, though it contains some of the most extravagant paradoxes that ever fell from the pen of a philosopher. Among other wonderful things, the author inculcates the possibility, if not the probability, that the nature of man may be improved to absolute perfection in body and mind, and his existence in this world protracted to immortality. So firmly does he seem to have been persuaded of the truth of this unphilosophical opinion, that he set himself seriously to consider how men should conduct themselves when the population should become too great for the quantity of food which the earth can produce; and the only way which he could find for counteracting this evil was, to check population by promiscuous concubinage and other practices, with an account of which we will not fully our pages. Yet we are told by La Lande, that this sketch is "only the outline of a great work, which, had the author lived to complete it, would have been considered as a monument erected to the honour of human nature!!!" La Lande, indeed, speaks of the author in terms of high respect; and his abilities are certainly unquestionable: but what shall we think of the morals of that man, who first pursued with malicious reports, and afterwards hired ruffians to assassinate*, the old Duke of Rochefoucault, in whose house he had been brought up; by whom he had been treated as a son; and at whose solicitation Turgot created for him a lucrative office; and by the power of the court raised him to all his eminence? There is a living English writer, who has laboured hard to prove that gratitude is a crime. Condorcet must surely have held the same opinion; and therefore could not blame those low-born tyrants who passed against him what we must think an unjust decree of accusation; for it was in some degree to his writings that those tyrants were indebted for their power.

About the end of the year 1786, Condorcet married Marie-Louise Sophie de Grouchy, whose youth, wit, and beauty, were less attractive in the eyes of a philosopher

Condorcet.

* *Jour. de Phys.* Nov. 1792.

Conferva fopher than the tender and courageous anxiety with which she watched the couch, and alluaged the sufferings, of the son of the president du Paty, who had been bitten by a mad dog. This union, however, we are told, was fatal to his repose; it tempted him into the dangerous road of ambition; and the idea of providing for a wife and daughter induced him to seek for offices which once he would have despised.

CONFERVA JUGALIS (see *CONFERVA*, *Encycl.*) is introduced here merely on account of a curious circumstance respecting it, which was communicated, not long ago, to the Philomatic Society at Paris. Citizens Charles and Romain Coquebert having collected some of this *Conferva* in the neighbourhood of Paris, ascertained, by means of an excellent microscope, constructed by Nairne and Blunt, that, in this species, there are male and female filaments, which unite by an actual copulation; that certain globules contained in the male filaments pass into the interior part of the female filaments; and that by this union there are formed in the latter seeds, or, if we may use the expression, small *ova*, which reproduce the species. This is the first instance, in the vegetable kingdom, of a reproduction absolutely analogous to that which we find among animals.—*Philosophical Magazine*, N^o 3.

May this fact be depended on? We question not, in the slightest degree, the veracity of the editor of the very respectable miscellany from which we have copied it; but we confess ourselves inclined to admit the physiological discoveries of citizen philosophers with great hesitation. The fact, if real, is certainly curious, and may lead to important conclusions; and we therefore recommend an investigation of its truth to our botanical readers.

CONGELATION. See **CHEMISTRY** in this Supplement, n^o 280—283.

CONTAGION (see *Encycl.*) is a subject on which much has been written to very little purpose. Of all the attempts which have been made to account for it, there is not one that can be thought satisfactory. This, however, is not perhaps a matter of great importance, if a method could only be discovered to stop the progress of contagion where it is known to have place. Among the many benefits which may be reaped from the late discoveries in chemistry, even this desideratum promises to be one; and we surely need not add one of the greatest. Dr James Carmichael Smyth, physician extraordinary to his Majesty, suggested, in the year 1795 or 1796, a process for determining the effect of the nitric acid in destroying contagion; and experiments, according to his directions, were made on board the *Union* and other ships at Sheerness.

The *Union* was an hospital ship, and the experiment on board her was conducted by Mr Menzies, late surgeon to his Majesty's sloop *Discovery*, and by Mr Baffan, surgeon of the *Union*; and when it is considered that fresh contagion was daily pouring into the hospital from the Russian vessels, which were at that time lying

in the Downs, and which had brought with them a species of fever that might in every sense of the word be termed an epidemic, it will be allowed, that the success which attended it was such that it cannot be too generally known.

The wards were extremely crowded, and the sick of every description lay in cradles, promiscuously arranged, to the number of nearly two hundred; of which about one hundred and fifty were in different stages of the above malignant fever, which was extremely contagious, as appeared evident from its rapid progress and fatal effects among the attendants on the sick and the ship's company.

The utensils and materials provided for the process were the following: A quantity of fine sand, about two dozen quart earthen pipkins, as many common tea-cups, some long slips of glass to be used as spatulas, a quantity of concentrated vitriolic (sulphuric) acid, and a quantity of pure nitre (nitrat of potash).

The process was conducted in the following manner: 1st, All the ports and scuttles were shut up; the sand, which had been previously heated in iron pots, was then scooped out into the pipkins by means of an iron ladle; and in this heated sand, in each pipkin, a small tea-cup was immersed, containing about half an ounce of the sulphuric acid, to which, after it had acquired a proper degree of heat, an equal quantity of nitrat of potash in powder was gradually added, and the mixture stirred with a glass spatula till the vapour arose from it in considerable quantity (A). The pipkins were then carried through the wards by the nurses and convalescents, who kept walking about with them in their hands, occasionally putting them under the cradles of the sick, and in every corner where any foul air was suspected to lodge. In this manner they continued fumigating, until the whole space between decks was fore and aft filled with the vapour, which appeared like a thick haze.

The vapour at first excited a good deal of coughing among the patients, which gradually ceased as it became more generally diffused through the wards; part of this effect, however, was to be attributed to the inattention of those who carried the pipkins, in putting them too near the faces of the sick; which caused them to inhale the strong vapour as it immediately issued from the cups.

The body-clothes and bed-clothes of the sick were as much as possible exposed to the nitrous vapour during the fumigation; and all the foul linen removed from them was immediately immersed in a tub of cold water, afterwards carried on deck, rinsed out, and hung up till nearly dry, and then fumigated before it was taken to the wash-house: a precaution extremely necessary in every case of infectious disorder. Due attention was also paid to cleanliness and ventilation.

It took about three hours to fumigate the ship. In about an hour after, the vapour having entirely subsided, the ports and scuttles were thrown open for the admission of fresh air. It could plainly be perceived that

(A) That the fumes of the mineral acids possessed the property of stopping contagion was proved by Morveau as far back as the year 1773, who, by means of the fumes of muriatic acid extricated from the muriat of soda (sea salt) by the sulphuric acid, purified the air of the cathedral of Dijon, which had been so much infected by exhumations that they were obliged to abandon the building. See **CHEMISTRY**, n 426. in this *Suppl.*

Contagion. that the air of the hospital was greatly sweetened even by this first fumigation. The process was repeated again next morning; and the people employed, being now better acquainted with it, were more expert, and finished the whole in about an hour's time. In an hour afterwards, the vapour having entirely subsided, the fresh air was freely admitted into the hospital as before. Fewer pipkins were employed for the evening fumigations than for those of the mornings, as the fresh air could not be admitted so freely after the former as the latter.

The pleasing and immediate effect of the fumigation in destroying the offensive and disagreeable smell, arising from so many sick crowded together, was now very perceptible, even to the nurses and attendants; the consequence of which was, that they began to place some degree of confidence in its efficacy, and approached the cradles of the infected with less dread of being attacked with the disorder: so that the sick were better attended, and the duty of the hospital was more regularly and more cheerfully performed. In short, a pleasing gleam of hope seemed now to cast its cheering influence over that general despondency, which was before evidently pictured in every countenance, from the dread and horror each individual naturally entertained of being, perhaps, the next victim to the malignant powers of a virulent contagion.

It is a remarkable fact, that from the 26th of November 1795, when the fumigation was first resorted to, till the 25th of December, not a person on board was attacked with the fever, though, in the three months preceding, more than one-third of all the people in the ship had been seized with the distemper, and of these more than one in four were carried off by it; and the probability is, that the sickness and mortality would have gone on, increasing in proportion to the diffusion of the contagion, and to the increasing despondency of the people, who considered themselves as so many devoted victims.

The advantage of the fumigation was not felt by the ship's company and attendants alone, whom it preserved from the baneful effects of the fever: the sick and convalescents derived almost an equal benefit from it. The symptoms of the disease were meliorated, and lost much of their malignant appearance; and the advantage of a pure air, and free from stench, to convalescents, may be readily conceived.

Great confidence is always dangerous. It proved so on the present occasion. On the 17th of December they imagined themselves so secure, that they discontinued the custom of fumigating morning and evening, thinking that once a day was sufficient. On the 25th, one of the nurses suffered a slight attack; and on the 26th, a marine, who, for a week before, had been in a state of intoxication, was seized with the fever, of which he died. These two accidents gave immediate alarm: they returned again to the practice of fumigating twice a-day; and from that time to the extermination of the disorder, there was not an instance of a person suffering from contagion on board the ship.

The success of the experiment was not confined to the Union: the power of the nitrous vapour to destroy contagion was equally displayed on board the Russian ships in which it was employed. The safety, too, with

which it may be employed, in any situation, without inconvenience or risk of fire, is another great recommendation in its favour.

From the description that has been given of the process, no person can be at any loss in resorting to the same kind of fumigation. It is only necessary to observe, for the sake of those who may not be versant in chemical pursuits, that the ingredients ought to be pure, and that metal vessels or rods must not be employed. Any kind of metal getting among the ingredients would cause the vapour to be very noxious instead of salutary. The fumes that rise should be white; if they are of a red colour, there is reason to suspect the purity of the ingredients.

The importance of this discovery need not be insisted on: it is equally applicable to every species of putrid contagion, even to the plague itself. It should therefore be used in all hospitals and parish workhouses; and should be constantly resorted to by the proprietors of all large works, on the first appearance of infectious disease among the people employed in them:—Indeed, it should be employed even as a preventive in all situations where a number of people, from the nature of their business, are obliged to be crowded together, or where, from local circumstances, there are reasons for suspecting that the purity of the air is injured by noxious exhalations or other causes. If there be any circumstances in which its utility may be called in question, it can only be in cases of inflammatory diseases; for in such superoxygenation has been found hurtful.

CONTRA-HARMONICAL Proportion, that relation of three terms, in which the difference of the first and second is to the difference of the second and third, as the third is to the first. Thus, for instance, 3, 5, and 6, are numbers contra-harmonically proportional; for $2 : 1 :: 6 : 3$.

CONTRA-Mure, in fortification, is a little wall built before another partition wall, to strengthen it, so that it may receive no damage from the adjacent buildings.

COOPER, an artificer who makes coops, casks, tubs, or barrels, *i. e.* all kinds of wooden vessels bound together by hoops. See *Encycl.*

The art of the cooper appears to be of great antiquity, and to have very soon attained to all the perfection which it possesses at present. This being the case, it is obvious that we can communicate no instruction to the cooper himself, and, on the subject of his art, very little that could be interesting to our other readers. In the *Encyclopedie Methodique* there is a long and verbose account of the tools or instruments employed by the cooper; of the kinds of timber proper for the different kinds of casks; of the methods of preparing the wood for his various purposes; of the manner in which he ought to hold the plane when dressing the staves; and of the time when it is proper to put the staves together, or, in other words, to mount the cask. From this detail we shall extract such particulars as appear to us to be least generally known, though perhaps of no great importance in themselves.

Notwithstanding the antiquity of the art of *cask-building*, there are some countries in which even now it is wholly unknown; and others where, though it is sufficiently known, yet, from the scarcity of wood or some other cause, earthen vessels, and skins lined with pitch,

Contagion
||
Cooper.

Cooper.

pitch, are preferred to wooden barrels for the holding and transporting of liquors. The Latin word *dolium*, which we translate "a cask," was employed by the Romans to denote earthen vessels used for this purpose; though the word *dolare*, from which it is derived, applies very well to our casks, which are composed of several pieces of wood hewn from the same tree, and fitted by planes before they be joined together. We are indeed certain that casks of the same kind with our own were in use among the Romans before the Christian era; for both Varro and Columella, in treating of the rural economy of their days, speak of vessels formed of several staves of wood bound together by circles or hoops. The merit of having invented such vessels is given by Pliny to certain people who lived at the foot of the Alps, and who in his days lined their casks with pitch.

At what period the fabrication of casks was introduced into Britain is unknown to us, though it is probable that we derived the art from the French, who might have it from the Romans.

We need hardly inform any of our readers, that a cask has the appearance of two truncated cones joined at their bases, or that the part where the junction appears to be made being the most capacious, or that of which the diameter is the largest, is vulgarly called the belly of the cask. These cones, however, were they completed, would not be regular, but rather *conoids*, being formed of pieces of timber, or staves, which are not straight lines as in the cone, but are curved from the vertex to the base.

In choosing his wood, if he can have a choice, the cooper prefers old and thick and straight trees, from which he hews thin planks to be formed into staves; and in France, where this art is practised on a large scale, the winter months are allotted for the preparation of the staves and bottoms, and the summer for putting them together or mounting the cask. The author of the article in the *Encyclopedie Methodique* directs the cooper, when dressing the staves with the plane, to cut the wood always across; a practice which we doubt not is proper, though we think it would not be easy to assign the reason of it. Planing is the most laborious and difficult part of the work; and there are but few coopers who plane quickly, and at the same time well. In shops where the work is distributed into parts, planing is reckoned a great object; and in France, before the revolution, a good plainer gained from three shillings and threepence sterling to four shillings and three farthings a-day.

In forming the staves, it must never be forgotten that each is to constitute part of a double conoid; that it must therefore be broadest at the middle, becoming gradually, though not in straight lines, narrower towards the extremities; that the outside across the wood must be wrought into the segment of a circle; and that the staff must be thickest near the middle, growing thinner, by very gentle degrees, towards the ends. To adjust accurately these different curves (for even the *narrowing* of the staves must be in a curve) to the size and intended shape of the cask, would require either great experience, or a larger portion of mathematical science than we have reason to think that many coopers possess. With respect to the inside of the staff, it is of little consequence whether it be rounded into the seg-

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ment of a circle or not, and therefore the cooper very seldom takes that trouble.

Cooper,
Copernicus.

The staves being all dressed and ready to be arranged in a circular form, it might be thought necessary, in order to make the seams tight, to trim the thin edges, which are to be joined together, in such a manner as that a ray passing from the outside of the cask through a seam to the centre, should touch the contiguous staves from the exterior to the interior side; in other words, that the thin edges should be sloped as the archstones of a bridge are sloped, so that the contiguous staves may be brought into firm contact throughout the whole joint. This, however, is not the practice of the cooper. With great propriety he brings the contiguous staves into contact at their inner surfaces only; so that by driving the hoops hard, he can make the joints much closer than he could possibly have done had the edges of the staves been so sloped as to permit them to touch each other throughout before being drove together by the compression of the hoops. This, together with giving to the staves the proper curvature, seems to be the only part of the cooper's work which deserves the name of art; for the driving of the hoops and the forming of the bottoms could certainly be accomplished by any carpenter, we had almost said by any man, though he had never seen a hoop driven or a bottom formed.

In many parts of Scotland, instead of ale or beer mugs, they use small hooped wooden vessels, of which the staves are feather-edged or dove-tailed into one another. This, as the staves are of different colours, increases the beauty of the vessel, and to a superficial observer appears to be an ingenious contrivance; but it adds nothing to the strength or tightness of the seam, and cannot be attended with the smallest difficulty. We think, indeed, that in a large cask or tub it would prove injurious to the seam; for either these dove-tails must be very thin slips raised from the interior edges of the staves, which in many cases could not be done if the wood were thoroughly seasoned; or if they be cut out like inverted wedges, the contiguous staves must be brought into contact from the interior to the exterior side previous to the driving of the hoops; and in that case, as we have seen, the seams could not be made completely tight.

COPERNICUS (Nicolaus), the restorer, if not the inventor, of the true system of the sun, holds so conspicuous a place in the republic of science, that every man of a liberal education must be interested both in the events of his life and in the history of his discoveries. Accordingly, in the *Encyclopædia*, we have given a short sketch of his history, as well as an account of what led him to suppose the sun placed in the centre of our system (see COPERNICUS, and ASTRONOMY, n^o 22. *Encycl.*) Since these articles were published, Dr Adam Smith's *Essays on Philosophical Subjects* have been given to the world; and in that which is intitled *The History of Astronomy*, we have an account of Copernicus's discoveries, so much more perspicuous and satisfactory than any thing which we have elsewhere seen on the subject, that we are persuaded our readers will be pleased to meet with it here.

"The confusion (says Dr Smith) in which the old hypothesis represented the heavenly bodies, was, as Copernicus himself tells us, what first suggested to him the

Copernicus. design of forming a new system, that these, the noblest works of Nature, might no longer appear devoid of that harmony and proportion which discover themselves in her meanest productions. What most of all dissatisfied him was, the notion of the equalizing circle, which, by representing the revolutions of the celestial spheres as equable only, when surveyed from a point that was different from their centres, introduced a real inequality into their motions; contrary to that most natural, and indeed fundamental idea, with which all the authors of astronomical systems, Plato, Eudoxus, Aristotle, even Hipparchus and Ptolemy themselves, had hitherto set out, that the real motions of such beautiful and divine objects must necessarily be perfectly regular, and go on in a manner as agreeable to the imagination as the objects themselves are to the senses. He began to consider, therefore, whether, by supposing the heavenly bodies to be arranged in a different order from that in which Aristotle and Hipparchus had placed them, this so much sought for uniformity might not be bestowed upon their motions. To discover this arrangement, he examined all the obscure traditions delivered down to us, concerning every other hypothesis which the ancients had invented for the same purpose. He found, in Plutarch, that some old Pythagoreans had represented the earth as revolving in the centre of the universe, like a wheel round its own axis; and that others, of the same sect, had removed it from the centre, and represented it as revolving in the ecliptic like a star round the central fire. By this central fire he supposed they meant the sun; and though in this he was very widely mistaken, it was, it seems, upon this interpretation that he began to consider how such an hypothesis might be made to correspond to the appearances. The supposed authority of those old philosophers, if it did not originally suggest to him his system, it seems at least to have confirmed him in an opinion which, it is not improbable, he had before-hand other reasons for embracing, notwithstanding what he himself would affirm to the contrary.

“ It then occurred to him, that if the earth was supposed to revolve every day round its axis, from west to east, all the heavenly bodies would appear to revolve, in a contrary direction, from east to west. The diurnal revolution of the heavens, upon this hypothesis, might be only apparent; the firmament, which has no other sensible motion, might be perfectly at rest; while the sun, the moon, and the five planets, might have no other movement beside that eastward revolution which is peculiar to themselves. That, by supposing the earth to revolve with the planets round the sun, in an orbit, which comprehended within it the orbits of Venus and Mercury, but was comprehended within those of Mars, Jupiter, and Saturn, he could, without the embarrassment of epicycles, connect together the apparent annual revolutions of the sun, and the direct, retrograde, and stationary appearances of the planets; that while the earth really revolved round the sun on one side of the heavens, the sun would appear to revolve round the earth on the other; that while she really advanced in her annual course, he would appear to advance eastward in that movement which is peculiar to himself. That, by supposing the axis of the earth to be always parallel to itself, not to be quite perpendicular, but somewhat inclined to the plane of her or-

bit, and consequently to present to the sun, the one pole when on the one side of him, and the other when on the other, he would account for the obliquity of the ecliptic; the sun's seemingly alternate progression from north to south, and from south to north, the consequent change of the seasons, and different lengths of days and nights in the different seasons.

“ If this new hypothesis thus connected together all these appearances as happily as that of Ptolemy, there were others which it connected together much better. The three superior planets, when nearly in conjunction with the sun, appear always at the greatest distance from the earth, are smallest, and least sensible to the eye, and seem to revolve forward in their direct motion with the greatest rapidity. On the contrary, when in opposition to the sun, that is, when in their meridian about midnight, they appear nearest the earth, are largest, and most sensible to the eye, and seem to revolve backwards in their retrograde motion. To explain these appearances, the system of Ptolemy supposed each of these planets to be at the upper part of their several epicycles in the one case, and at the lower in the other. But it afforded no satisfactory principle of connection, which could lead the mind easily to conceive how the epicycles of those planets, whose spheres were so distant from the sphere of the sun, should thus, if one may say so, keep time to his motion. The system of Copernicus afforded this easily, and like a more simple machine, without the assistance of epicycles, connected together, by fewer movements, the complex appearances of the heavens. When the superior planets appear nearly in conjunction with the sun, they are then in the side of their orbits, which is almost opposite to, and most distant from, the earth, and therefore appears smallest and least sensible to the eye. But as they then revolve in a direction which is almost contrary to that of the earth, they appear to advance forward with double velocity; as a ship that sails in a contrary direction to another, appears from that other to sail both with its own velocity and the velocity of that from which it is seen. On the contrary, when those planets are in opposition to the sun, they are on the same side of the sun with the earth, are nearest it, most sensible to the eye, and revolve in the same direction with it; but as their revolutions round the sun are slower than that of the earth, they are necessarily left behind by it, and therefore seem to revolve backwards; as a ship which sails slower than another, though it sails in the same direction, appears from that other to sail backwards. After the same manner, by the same annual revolution of the earth, he connected together the direct and retrograde motions of the two inferior planets, as well as the stationary appearances of all the five.

“ Thus far did this new account of things render the appearances of the heavens more completely coherent than had been done by any of the former systems. It did this, too, by a more simple and intelligible, as well as more beautiful machinery. It represented the sun, the great enlightener of the universe, whose body was alone larger than all the planets taken together, as established immovable in the centre, shedding light and heat on all the worlds that circulated around him in one uniform direction, but in longer or shorter periods, according to their different distances. It took away the diurnal revolution of the firmament, whose rapidity, upon

Copernicus upon the old hypothesis, was beyond what even thought could conceive. It not only delivered the imagination from the embarrassment of epicycles, but from the difficulty of conceiving these two opposite motions going on at the same time, which the system of Ptolemy and Aristotle bestowed upon all the planets; I mean, their diurnal westward, and periodical eastward revolutions. The earth's revolution round its own axis took away the necessity for supposing the first, and the second was easily conceived when by itself. The five planets, which seem, upon all other systems, to be objects of a species by themselves, unlike to every thing to which the imagination has been accustomed, when supposed to revolve along with the earth round the sun, were naturally apprehended to be objects of the same kind with the earth, habitable, opaque, and enlightened only by the rays of the sun. And thus this hypothesis, by classing them in the same species of things, with an object that is of all others the most familiar to us, took off that wonder and uncertainty which the strangeness and singularity of their appearance had excited; and thus far, too, better answered the great end of philosophy.

“Neither did the beauty and simplicity of this system alone recommend it to the imagination; the novelty and unexpectedness of that view of nature which it opened to the fancy, excited more wonder and surprise than the strangest of those appearances, which it had been invented to render natural and familiar, and these sentiments still more endeared it. For though it is the end of philosophy to allay that wonder which either the unusual or seemingly disjointed appearances of Nature excite, yet she never triumphs so much as when, in order to connect together a few, in themselves perhaps inconsiderable objects, she has, if I may say so, created another constitution of things, more natural indeed, and such as the imagination can more easily attend to, but more new, more contrary to common opinion and expectation, than any of those appearances themselves. As in the instance before us, in order to connect together some seeming irregularities in the motions of the planets, the most inconsiderable objects in the heavens, and of which the greater part of mankind have no occasion to take any notice during the whole course of their lives, she has, to talk in the hyperbolical language of Tycho Brahé, moved the earth from its foundations, stopt the revolution of the firmament, made the sun stand still, and subverted the whole order of the universe.

“Such were the advantages of this new hypothesis, as they appeared to its author when he first invented it. But though that love of paradox, so natural to the learned, and that pleasure which they are so apt to take in exciting, by the novelty of their supposed discoveries, the amazement of mankind, may, notwithstanding what one of his disciples tells us to the contrary, have had its weight in prompting Copernicus to adopt this system; yet when he had completed his Treatise of Revolutions, and began coolly to consider what a strange doctrine he was about to offer to the world, he so much dreaded the prejudice of mankind against it, that, by a species of continence of all others the most difficult to a philosopher, he detained it in his closet for thirty years together. At last, in the extremity of old age, he allowed it to be extorted from him, but died as soon as it was printed, and before it was published.”

This noble theory, however, being repugnant to the

prejudices of habit and education, was at first coldly received, or utterly rejected, by every class of men. The astronomers alone favoured it with their notice, though rather as a convenient hypothesis than an important truth. By the vulgar it was considered as a chimera, belied by the clearest evidence of our senses; while the learned beheld it with disdain, because it militated against the fanciful distinctions and the vague erroneous tenets of the Peripatetic philosophy, which no one had ventured to call in question; and it is amusing to observe with what dexterity the Copernicans, still using the same weapons, endeavoured to parry the blows of their antagonists. Its real merits and blemishes appear to have been overlooked by both parties. Brahé framed a sort of intermediate system; but this Danish astronomer was more remarkable for his patience and skill in observing the heavens, than for his talents of philosophical investigation. Towards the commencement of the 16th century, a new order of things emerged. The system of Copernicus became generally known and daily made converts. Its reception alarmed the ever-watchful authority of the church, roused her jealousy, and at length provoked her vindictive artillery. The *ultima ratio theologorum* was pointed at the head of the illustrious Galileo, whose elegant genius discovered the laws of motion, extended the science of mechanics, and added lustre and solidity to the true system of the universe. From the storms of persecution Copernicus himself had been exempted only by a timely death.

COPPER, one of the metals; for the properties of which, see CHEMISTRY-Index in this Supplement.—The Chinese have a metal which they call *pe-tung*, but which Sir George Staunton denominates

White COPPER. This metal has a beautiful silver-like appearance, and a very close grain. It takes a fine polish, and many articles of neat workmanship, in imitation of silver, are made of it. An accurate analysis has determined it to consist of copper, zinc, a little silver; and in some specimens a few particles of iron and of nickel have been found. From this account it would appear that white copper is not an artificial mixture of metals, but is found native in the mine. Yet in the very same page and paragraph, Sir George proceeds to say that Dr Gallan was informed at Canton, that the artists, in making their *pe-tung*, reduce the copper into as thin sheets or laminæ as possible, which they make red-hot, and increase the fire to such a pitch as to soften in some degree the laminæ, and to render them ready almost to flow. In this state they are suspended over the vapour of their purest *tu-te-nag* or zinc, placed in a subliming vessel over a brisk fire. The vapour thus penetrates the heated laminæ of the copper, so as to remain fixed with it, and not to be easily dissipated or calcined by the succeeding fusion it has to undergo. The whole is suffered to cool gradually, and is then found to be of a brighter colour, and of a closer grain, than when prepared in the European way. Surely this is not the white copper, which consists of copper, zinc, silver, iron, and nickel.

CORK is the exterior bark of a tree which has been described in the Encyclopædia. When the tree is about 15 years old it is fit to be barked, and this can be done successively for eight years. The bark always grows up again, and its quality improves as the age of the tree increases. It is commonly singed a little over a

Cornua. strong fire or glowing coals, or laid to soak a certain time in water; after which it is placed under stones in order to be pressed straight. We were wont to procure the greater part of our cork from the Dutch, who brought it principally from France; but they imported some also from Portugal and Spain.

This tree, as well as the uses to which its bark is put, was known to the Greeks and the Romans; by the former of whom it was called *φειλλος*, and by the latter *suber*. By the Romans, as we learn from Pliny, it was even employed to stop vessels of every kind; but its application to this use seems not to have been very common till the invention of glass bottles, of which Professor Beckmann finds no mention before the 15th century.

In later times, some other vegetable productions have been found which can be employed instead of cork for the last mentioned purpose. Among these is the wood of a tree common in South America, particularly in moist places, which is called there *monbin* or *monbain*, and by botanists *spondias lutea*. This wood is brought to England in great abundance for that use. The spongy root of a North American tree, known by the name of *nyssa*, is also used for the same end, as are the roots of liquorice, which, on that account, is much cultivated in Slavonia, and exported to other countries.

CORNUA AMMONIS, in natural history, are fossil shells, of which a pretty full account is given in the Encyclopædia. See CORNU *Ammonis* and SNAKE-Stones. It was observed in the last of these articles, that few, if any, of these shells are known in their recent state, or as occupied by the living animal; but some authors have asserted, on the authority of Linnæus, that *ammonites*, with shells similar to all the varieties of the fossil ones, are yet found alive in the depth of the sea. We are much inclined to embrace this opinion; but it has been controverted by *M. de Lamanon*, who accompanied *La Perouse* on his voyage of discovery, by such arguments as we know not how to answer. This unfortunate naturalist (see LAMANON in this Supplement) allows that there are still in the sea living *cornua ammonis*; but he thinks that they are in very small numbers, and materially different from the greater part of the fossil ones. According to him, these last ought to be considered as a race, formerly the most numerous of all, of which, either there are no descendants, or those descendants are reduced to a few degenerate individuals. That there are no living animals with shells of the very same kind with some of the fossil *cornua ammonis*, the following observations he considers as a sufficient proof.

“The fossil shells are very light and thin, whereas the shells of those animals that live in very deep water are always thick and ponderous; besides, the form of the fossil *cornua ammonis* points out to us, in some measure, the organization of the animal which inhabited it. The celebrated Jussieu proved, in 1721, that there existed a very close analogy between the ammonite and

nautilus (A). It is well known that the *nautilus*, by filling or emptying a part of its shell, has the power of remaining stationary in any depth it pleases: the same was doubtless the case with the ammonite; and if this species still abounds in the sea, it would surely be occasionally discovered by sailors.

“The waves also would throw fragments of it on the shore; fishermen might sometimes entangle it in their nets; or, at least, there would be fragments sticking to the lead of the sounding line when ascertaining great depths. It may also be added, that if the ammonites never quitted the abyss of the sea, those which are found petrified would not be constantly met with on the same level, and in the same bed, as those shell-fish that only inhabit the shallows. There are, however, found in Normandy, Provence, Touraine, and a multitude of other places, ammonites mixed with turbines, *buccina* (whelks), and other littoral shells. They are found, besides, at every degree of elevation from below the level of the sea to the summits of the highest mountains. Analogy also leads us to suppose, that Nature, who has given eyes to the *nautilus*, has not refused them to the ammonite: now what use could these be of if they remained confined to those depths which the light is unable to penetrate?

“The extinction of the ancient race of ammonites is therefore an established fact, which no rational supposition can destroy; and this fact is undoubtedly the most surprising of any that is presented to us in the history of aquatic animals. The discovery of a few living species of *cornua ammonis* does not destroy the truth of this, for these ammonites are very different from those which are found petrified. They are extremely rare, and cannot be looked up to as the representatives of the old ammonites, so varied in their species, and the number of which in the ancient ocean was probably far more considerable than that of all the other shells besides.”

To every univolve shell, rolled in a spiral, so as that a horizontal plane will divide it into two equal parts, formed of united spirals, and bearing a certain proportion to each other, our author gives the name of an *ammonite*. “I thought it absolutely necessary (says he) to ascertain the precise meaning of the term *ammonite*, previous to describing that which I found during our voyage round the world. The form of this is almost orbicular, the long diameter being to the short one as three lines to two lines and three quarters. The first spire is by far the largest, occupying nearly half of the longitudinal diameter. The summit is placed at the distance of about two-thirds of this diameter; it is terminated on the right side by a very small knob visible only through a magnifier, thus differing from the ammonite of Rimini, which besides is microscopical and celled, the inside of this which we are now speaking of being entirely plain. The number of spiral circumvolutions is four and a half; they are equally convex on both sides, and are fixed on a plane, dividing the shell into

(A) There are, however, some striking internal differences: first, the partitions in the shell of the *nautilus* are more curved than those of the ammonite: secondly, the ammonite wants the small hole which communicates from one cell to the other.

Cornua.

into two equal parts: there is on each side a kind of boss formed by the increase of the perpendicular diameter of the spires, in proportion as they recede from the centre. The surface is smooth; the back is armed with a flat, even, brittle crest, as thin as paper, surrounding it on every side like a ruff: it is about half a line broad, extends over the summit of the spires, and serves to join them together. The mouth of the shell is nearly triangular; its edges project in the form of lips, and are rounded at the border. I have often found this ammonite enclosed in the stomach of the bonetta (*Scomber pelamis*, Linn.), caught in the South Sea, between the tropics, where no bottom was found with a line of more than two hundred fathoms. These shells were covered with a black clayey mud. Their size varies from one to four lines across; they are consequently the largest living ammonites that have yet been discovered."

It is well known for what purpose the modern philosophers of France have been so indefatigable in the study of natural history; and there can be little doubt but that it is to serve the same purpose that Lamanon thus reasons for the destruction of the ancient race of ammonites in some universal convulsion of the world. But supposing his arguments conclusive, they affect not the truth of the Jewish and Christian scriptures. It is nowhere said in the Bible, that the *matter* of this globe was brought into being at the moment when Moses represents the Creator as beginning to reduce the chaos into order; and it is more than insinuated that there will be a *new earth* after the present system of things shall be dissolved. That *new earth* will certainly be stored with some kind of inhabitants; and could it be demonstrated that there was an *old earth*, previous to the era of the Mosaic cosmogony, inhabited by creatures rational and irrational, and that the fossil *cornua ammonis* make part of the wreck of that system, the cause of revelation would remain uninjured. "Moses, as a real philosopher* has well observed, writes the history, not of this globe through all its revolutions, but of the race of Adam."

* Professor
Robison of
Edinburgh.

This secret attack, therefore, made by Lamanon against that religion of which he once professed to discharge the duties of a priest, is nothing more than *telum imbelles sine ictu*. Yet it may be worth some naturalist's while to enquire, whether, though feeble, it has been fairly made. We confess that our own suspicions of unfair dealing are strong; for when a man of science contradicts himself in the course of two pages, the blunder must be attributed to some other source than mere inadvertency. M. de Lamanon wishes to prove, among other things, that the ancient ammonites did not inhabit great depths of the sea; and that Linnæus was mistaken when he supposed that in great depths they may still be found. Yet he himself tells us, that he frequently caught ammonites in the South Sea, where no bottom was to be found with a line of *more than 200 fathoms*; and to put it beyond a doubt that the animals had been at that bottom, he informs us, that their shells were covered with a *black clayey mud*. It is true these ammonites were but small; while of 300 varieties of fossil ammonites which he mentions, some, he says, have been found ten feet in circumference. But is it certain, that these large shells were real *cornua ammonis*? If they agree not exactly with our author's description of

the shell of the ammonite (a fact into which we have had no opportunity of inquiring), his arguments for the extinction of the ancient race are gross sophisms, unworthy of a man either of science or of candour.

Correction.

CORRECTION-HOUSE is a prison where idle vagrants are compelled to work, and where persons guilty of certain crimes suffer punishment and make reparation to the public. Of the former kind of *correction-houses*, perhaps enough has been said in the Encyclopædia under the title *WORK-HOUSE*; but of the latter very little will be found in that work under the titles BRIDEWELL and IDLENESS.

Perhaps houses of correction, as means of punishment, are not, in this country, employed so frequently as justice and expediency seem to require. In the opinion of Dr Paley, whose opinions are always worthy of attention, it is one of the greatest defects of the laws of England (and we may say the same thing of the laws of Scotland), that "they are not provided with any other punishment than that of death, sufficiently terrible to keep offenders in awe. Transportation, which is the punishment second in the order of severity, answers the purpose of example very imperfectly; not only because exile is in reality a slight punishment to those who have neither property, nor friends, nor regular means of subsistence at home, but because the punishment, whatever it be, is unobserved and unknown. A transported convict *may* suffer under his sentence, but his sufferings are removed from the view of his countrymen; his misery is unseen; his condition strikes no terror into the minds of those for whose warning and admonition it was intended. This chasm in the scale of punishment produces also two farther imperfections in the administration of penal justice; of which the first is, that the same punishment is extended to crimes of very different characters and malignancy; and the second, that punishments, separated by a great interval, are assigned to crimes hardly distinguishable in their guilt and mischief."

Perhaps this chasm might be properly filled up by houses of correction under judicious management, which might likewise promote another important purpose, better than the punishments in common use.

The end of punishment is twofold, *amendment* and *example*. In the first of these, the *reformation* of criminals, little has ever been effected, and little indeed seems practicable by the punishments known to the laws of Britain. From every species of punishment inflicted among us, from imprisonment and exile, from pain and infamy, malefactors return more hardened in their crimes, and more instructed. The case we think would often be different when they returned to the world from a well-regulated house of correction. As experience is the only safe guide in matters of legislation and police, we shall lay before our readers *M. Thoun's* account of the house of correction at Amsterdam, which seems to corroborate our opinion.

The Amsterdam correction house, from the employment of the prisoners confined in it, is called the *rasping-house*, and is destined to the reception of those malefactors whose crimes do not amount to a capital offence. Their punishment cannot so properly be denominated solitary confinement as a sequestration from society during a limited term of years. The building is situated in a part of the suburbs to the north-east of the city.

The.

Correction. The exterior has nothing remarkable, either with respect to form or extent. It is detached from the street by a spacious court, which contains the keeper's lodge, together with apartments for the different servants belonging to the establishment. Over the gate, which opens from this court into the prison, are placed two statues, as large as life, representing two men in the act of sawing a piece of logwood.

The inner court is in the form of a square, round which are arranged the apartments of the prisoners, together with the necessary warehouses. One part of the ground story is divided into different chambers; the other serves as a depot for the logwood, and the implements employed in its preparation.

The keeper, whose countenance, contrary to the general custom of persons of his profession, was strongly indicative of urbanity and gentleness, introduced M. Thouin into an apartment where two prisoners were at work in sawing a large log of Campeachy wood. The saw is composed of four blades joined together, with very strong, large, and sharp teeth, which make a scissure in the wood of nearly two inches in breadth. The operation is repeated, till the pieces become too small to undergo the saw, when they are ground in mills peculiarly constructed for this purpose.

This employment requires an extraordinary exertion of strength, and is at first a severe penance even to robust persons; but habit, address, and practice, soon render it easy; and the prisoners in a short time become competent to furnish, without painful exertion, their weekly contingent of 200 lb. weight of sawed pieces. After completing this task, they even find time to fabricate a variety of little articles in wood and straw, which they sell to those who visit the prison, or dispose of, by means of agents, in the town.

M. Thouin next inspected three apartments of different dimensions, which opened into the inner court. The one was inhabited by four, the second by six, and the third by ten prisoners. The furniture of the rooms consisted in hammocks, with a matras, a blanket, and a coverlid to each, tables, chairs, and stools, glass, &c. earthen vessels, and various other articles of convenience. Every thing in these apartments was distinguished by neatness and propriety; and notwithstanding the number of inhabitants allotted to each, was fully adequate to the dimensions of the rooms; the senses were not offended with any disagreeable scent, and the air was in every respect as pure and wholesome as the surrounding atmosphere.

In an obscure part of the building are a number of cells, in which formerly those prisoners who revolted against the proper subordination of the place, or ill-treated their comrades, were confined for a few days. But the keeper assured M. Thouin that these cells had not been made use of for upwards of 10 years. They are dark gloomy dungeons, with only a small aperture for the admission of light and air. The suppression of this barbarous and coercive punishment does honour to the humanity of government.

The store-rooms are filled with various kinds of wood for the purposes of dyeing; as the haemotoxylum campechianum, the morus tinctoria, the caesalpinia sappan, &c. They are all exotics, with the exception of the Evonymus Europæus. The warehouses were not of sufficient extent to contain the quantity of wood,

which was deposited in piles in different parts of the Correction. court.

The prisoners, amounting to 76 in number, were uniformly habited in coarse woollens; wear very good stockings, large leather shoes, white shirts, and caps or hats. They are, by the rules of the house, obliged to frequent ablutions, which greatly contribute to the preservation of their health. There was only one sick person amongst them; and, what is not a little remarkable, almost all the prisoners had formerly lived in large commercial towns; very few villagers were amongst them. They had all been sentenced to imprisonment for theft; but it depends upon themselves, by reformation and good behaviour, to shorten the term of their confinement, which many of them frequently do.

The keeper, whose humanity to the unfortunate persons committed to his care entitles him rather to the title of their protector than their gaoler (and M. Thouin informs us, that the prisoners generally called him by no other name than *father*), assists them with his counsels and friendly admonitions. He registers every week, in a book appropriated to this purpose, both the instances of good and bad behaviour, which is annually submitted to the examination of the magistracy, who, from this report, abridge or prolong the term of confinement, according to the degree of indulgence which each prisoner appears to merit. Cases frequently happen where a malefactor, condemned to an imprisonment of eight years, by his good behaviour procures his enlargement at the expiration of four; and so in proportion for a shorter term. But great attention is paid to discriminate between actual reform and hypocritical artifice.

The reward of good behaviour is not, however, confined to, or withheld till, the period of actual liberation. Their restoration to society is preceded by a progressive amelioration of their lot. Their work is gradually rendered less laborious, they are accommodated with separate apartments, and employed in the services of domestic economy. The keeper even entrusts them with commissions beyond the precincts of the prison; and scarce a single instance has occurred of their abusing this indulgence. By this prudent management, a considerable saving is effected in the expence of the establishment, at the same time that it tends to wear away prejudice, and to initiate the prisoners by gradual advances into the reciprocal duties of social life.

M. Thouin made particular inquiries whether it was customary for persons after their discharge to be confined a second and third time, as is but too often the case in many countries, for a repetition of their offence. He was informed, that such instances very rarely occur; but the case is not without precedent, as he observed in the person of a young Jew, who was then in the rasping-house for the third time. The case of this man is somewhat extraordinary. During the period of his detention, he always conforms, with the most scrupulous observance, to the rules of the place, and gives general satisfaction by his exemplary conduct. But such, as he himself avowed to our traveller, is his constitutional propensity to thieving, that no sooner is the term of his imprisonment elapsed, than he returns with redoubled ardour to his lawless courses. It is not so much for the sake of plunder, as to gratify his irresistible impulse, that he follows this vicious life; and M. Thouin adds, that he recounted his different exploits with as much exultation

Correction, exultation and triumph as a veteran displays when re-hearing his warlike achievements.

Another salutary regulation in this institution, from which the best consequences result, is the indulgence granted to the prisoners of receiving the visits of their wives and mistresses twice every week. Proper care, however, is taken to guard against the introduction of disease; and the ladies, in one sense, purchase their admission by giving a trifling sum of money at the gate, which becomes the perquisite of the aged prisoners, whose wants are of a different nature from their youthful comrades. Thus the pleasures of one class contribute to the comforts of the other; and the entrance money, trifling as it is, keeps away a croud of idle vagabonds, who have no acquaintance with the prisoners. The ladies at their visits are permitted to eat and drink with their lovers; and when the conversation becomes too animated for a third person to be present, the rest of the company obligingly take the hint, and leave them to enjoy a *tete-a-tete*.—By this prudent regulation, many hurtful consequences attendant on a total seclusion from female society are guarded against.

M. Thouin concludes his account with observing, that the rasing-house at Amsterdam bears a greater resemblance to a well-ordered manufactory than to a prison. It were to be wished that all similar institutions were conducted upon a similar plan (A).

So says our author: But though we have admitted experience to be the only safe guide in regulating institutions of this kind, we cannot help thinking that the plan is susceptible of improvement. We do not see the propriety of locking up four, six, or ten thieves in the same apartment. The uncommon attention to cleanliness, which distinguishes all ranks among the Dutch, may indeed prevent the room from having an offensive scent; but what can prevent such a number of unprincipled persons from corrupting each other in Holland, as we know that they do in Great Britain? The introduction of females of loose character to felons suffering punishment for their offences in a prison, is a practice which we trust will be approved only by philosophers of the French school. The British philosopher, whom we have already quoted with approbation, is of opinion, and we heartily agree with him, that “of reforming punishments, none promises so much success as that of solitary imprisonment, or the confinement of criminals in separate apartments. This improvement of the Amsterdam house of correction would augment the terror of the punishment, would seclude the criminal from the society of his fellow-prisoners, in which society the worse are sure to corrupt the better; would wean him from the knowledge of his companions, and from the love of that turbulent pernicious life in which his vices had engaged him; would raise up in him reflections on the folly of his choice, and dispose his mind to such bitter and continued penitence, as might produce a lasting alteration in the principles of his conduct.”

In some houses of correction, the prisoners are subjected to the discipline of flagellation at stated intervals.

We will not take it upon us to say that this punishment is never proper; but we are fully convinced that it is not often so; and that flagellation, if it can at all produce any good effect, must be administered in private. It is observed by Fielding, who well understood human nature, that fasting is the proper punishment of profligacy, not any punishment that, like flagellation, is attended with shame. Punishment (says he) that deprives a man of all sense of honour, never will contribute to make him virtuous; and we believe it is generally admitted by the gentlemen of the army, that a soldier who has suffered the punishment of whipping seldom proves good for any thing.

COURTESEY OF SCOTLAND. See LAW (*Encycl.*), Part III. sect. ix. § 28.

COWRY-SHELLS, the lowest money in some parts of the East. See MONEY (*Encycl.*), where they are called *karis*.

CRANE, in mechanics, a machine used for raising or lowering great weights. For the principles on which these machines act, see DYNAMICS in this *Supplement*, and likewise MECHANICS, *Encycl.* where descriptions are given of several very powerful cranes.

The crane in common use is employed with some danger to those who work it; and therefore a machine of this kind, acting upon a simple and certain principle, by which the men walking in the wheel can lower goods with safety as well as expedition, has long been considered as a great desideratum in mechanics. Repeated premiums have been offered by the *Society for the Encouragement of Arts* to induce ingenious men to attempt the invention of such a machine; and various have been the contrivances for accomplishing so desirable a purpose. A clergyman, who subscribes E. C. we suppose as the initials of his name, proposes, through the medium of the *Repertory of Arts*, to accomplish it merely by introducing the action of a worm or screw into the crane.

Whenever a worm of two threads is introduced into a machine, all retrograde motion is stopped, unless that worm receive its reaction from the first moving force; for, powerfully as a worm acts upon a wheel, a wheel has no power upon a worm, whatever force may be applied to it. Suppose, then, the first motion in a crane were given by a worm upon the axis of the wheel in which the man walks, the man would have perfect command of the machine, to raise or lower the goods at pleasure, with the remotest possibility of being overpowered by the descending weight.

“Were I to construct (says the author) a crane upon this principle, I would have the axis of the wheel in which the man walks, and the axis of the worm, in separate parts, and occasionally united by a coupling-box. When goods were to be raised, the two axes should be connected; when lowered, they might be disunited, and the worm turned by a winch, which would be done much more expeditiously that way than by the wheel. For the reasons before suggested, the descent of the weight could be accelerated or stopped at pleasure, at the discretion of the person turning the winch.

“This contrivance might be not inconveniently applied

(A) We do not know that M. Thouin's journal of his travels has been yet published. Extracts from it have been inserted into the *Decade*, a periodical publication at Paris, whence this account of the *Amsterdam house of correction* was first copied into the *Monthly Magazine* for June 1798.

Crane.

plied to a crane already erected upon the common principle: Let there be a wheel put upon any convenient axis in the machine as it now stands; upon this let there lie a worm, that can be thrown in or out of gear at pleasure; and let the lever by which it is done lie within reach of the man's hand in the wheel. The goods being fastened to the crane, and raised off the floor of the warehouse ready for letting down, the man puts the worm into gear, leaves the wheel, and lets the goods down by the winch. Provided it can be conveniently done, it would be advisable to throw the wheel in which the man walks out of gear when the winch is made use of; this, however, I should apprehend, would not be a matter of absolute necessity."

Our author is aware of two objections which may be urged against the introduction of a worm into a crane in the manner which he proposes. The first arises from the slowness of the motion produced by the turning of a screw, which he considers as unworthy of regard; because the necessary speed is to be gained by the first pair of wheels and the diameter of the barrel of the windlafs.

To the second, arising from the supposed greater friction between a worm and wheel, he replies, that as the friction between the teeth of two wheels (if not formed on the true epicycloidal principle) must, while it lasts, be greater than between a worm and wheel for the same space of time, it seems no unreasonable supposition that the aggregate of friction will, in the two cases, nearly balance each other; especially if it be taken into the account, that to obtain the power of one worm and wheel, there will be, in most cases, required two pair of wheels, and two additional axes—all which will add to the friction. But, granting the balance of friction to be against the action of the worm, the power to overcome it is greater in proportion than to overcome the friction of two wheels.

Mr James Whyte of Chevening, in the county of Kent, whose improvement in the construction of pulleys has, with due respect, been noticed elsewhere*, gives, in the *Transactions of the Society for the Encouragement of Arts, &c.* the following description of a new crane for wharfs:

* See *Mechanics*, n^o 27. *Encycl.*

Plate XX.

A (fig. 1.), a circular inclined plane, moving on a pivot underneath it, and carrying round with it the axis E. A person walking on this plane, and pressing against the lever B, throws off the gripe D, by means of an iron rod C; and thus admits the plane and its axis to move freely, and raise the weight G by the coiling of the rope F round the axis E.

To shew more clearly the construction and action of the lever and gripe, a plan of the circular inclined plane, with the lever and gripe, is added (see fig. 2.), where B represents the lever, D the spring or gripe. In this plan, when the lever B is in the situation in which it now appears, the spring or gripe D presses against the periphery of the plane, as shewn by the double line, and the machine cannot move; but when the lever B is pressed out to the dotted line H, the gripe is also thrown off to the dotted line I, and the whole machine left at liberty to move. One end of a rope or cord, of a proper length, is fixed near the end of the lever B, and the other end made fast to one of the uprights, serving to prevent the lever moving too far when pressed by the man.

The properties of this crane, for which the premium

of 40 guineas was adjudged by the society to the inventor, are as follows:

Crane,
Cros.

1. It is simple, consisting merely of a wheel and axle.
2. It has comparatively little friction, as is obvious from the bare inspection of the figure.
3. It is durable, as is evident from the two properties above mentioned.
4. It is safe; for it cannot move but during the pleasure of the man, and while he is actually pressing on the gripe-lever.
5. This crane admits of an almost infinite variety of different powers; and this variation is obtained without the least alteration of any part of the machine. If, in unloading a vessel, there should be found goods of every weight, from a few hundreds to a ton and upwards, the man that does the work will be able so to adapt his strength to each as to raise it in a space of time proportionate to its weight; he walking always with the same velocity as nature and his greatest ease may teach him.

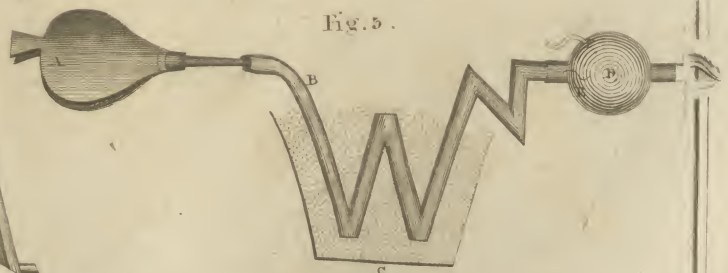
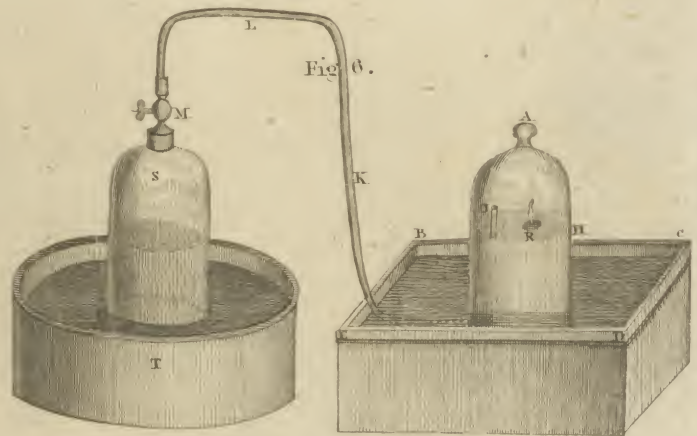
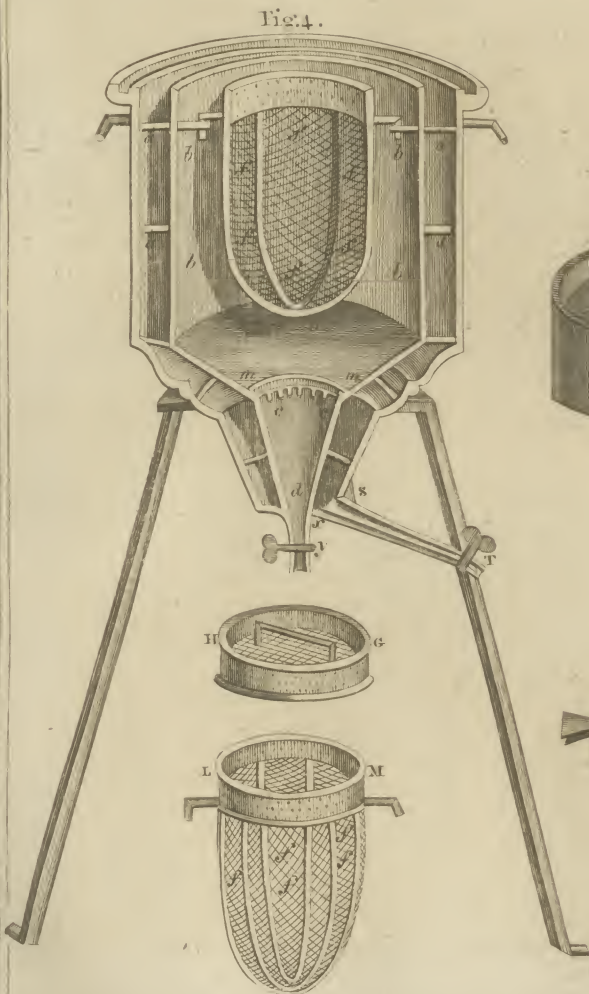
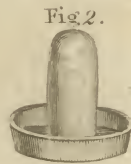
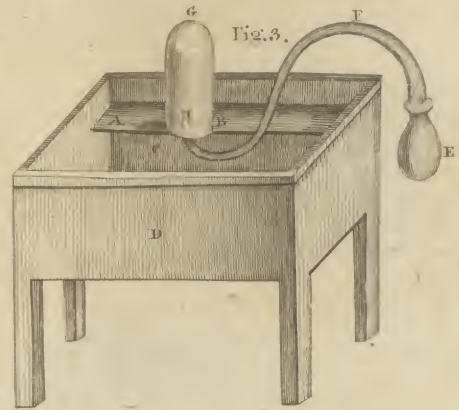
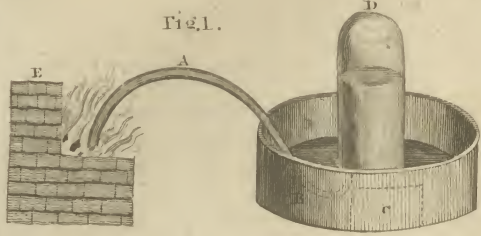
It is a great disadvantage in some cranes, that they take as long time to raise the smallest as the largest weight, unless the man who works them turn or walk with such velocity as must soon tire him. In other cranes, perhaps, two or three different powers may be procured; to obtain which, some pinion must be shifted, or fresh handle applied or resorted to. In this crane, on the contrary, if the labourer find his load so heavy as to permit him to ascend the wheel without its turning, let him only move a step or two toward the circumference, and he will be fully equal to the task. Again, if the load be so light as scarcely to resist the action of his feet, and thus to oblige him to run through so much space as to tire him beyond necessity, let him move laterally towards the centre, and he will soon feel the place where his strength will suffer the least fatigue by raising the load in question. One man's weight applied to the extremity of the wheel would raise upwards of a ton; and it need not be added, that a single-sheaved block would double that power. Suffice it to say, that the size may be varied in any required ratio; and that this wheel will give as great advantage at any point of its plane as a common walking-wheel of equal diameter, as the inclination can be varied at pleasure, as far as expediency may require. It may be necessary to observe, that what in the figure is the frame, and seems to form a part of the crane, must be considered as a part of the house in which it is placed; since it would be mostly unnecessary should such cranes be erected in houses already built. With respect to the horizontal part, by walking on which the man who attends the gib occasionally assists in raising the load, it is not an essential part of this invention, where the crane is not immediately contiguous to the gib, although, where it is, it would be certainly very convenient and economical.

CRANE is also a popular name for a sphyon, employed in drawing off liquors.

CROSS, in *surveying*, is an instrument consisting of a brass circle, divided into four equal parts by two lines crossing each other in the centre. At each extremity of these lines is fixed a perpendicular sight, with small holes below each slit, for the better discovering of distant objects. The cross is mounted on a staff or stand, to fix it in the ground, and is very useful for measuring small pieces of land, and taking offsets, &c.

Cross-staff, or Fore-staff, is a mathematical instrument

of



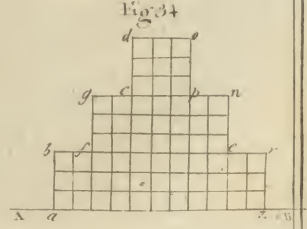
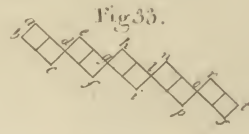
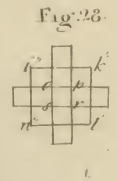
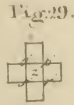
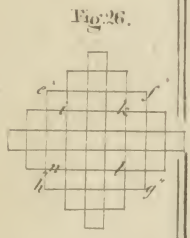
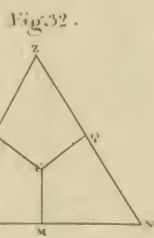
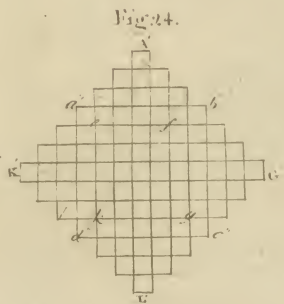
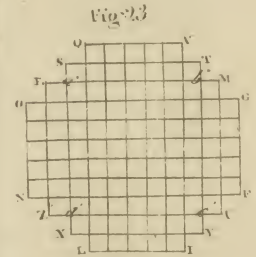
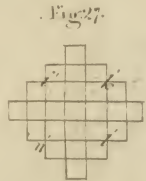
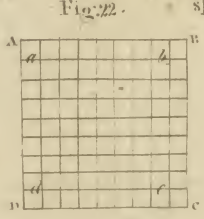
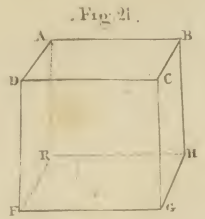
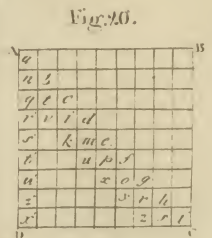
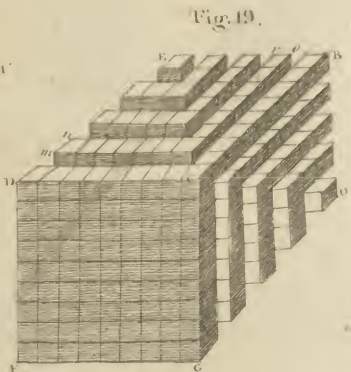
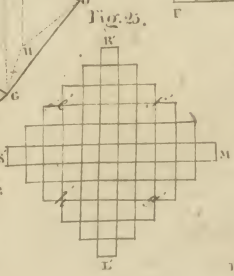
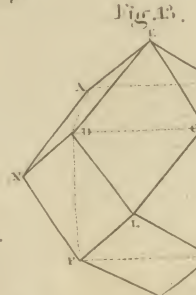
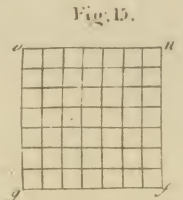
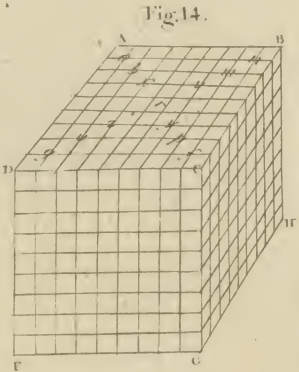
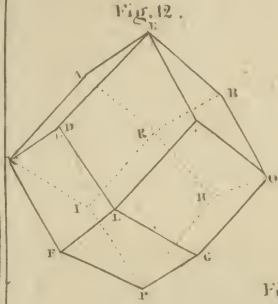
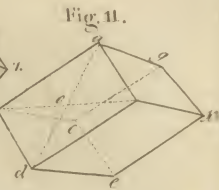
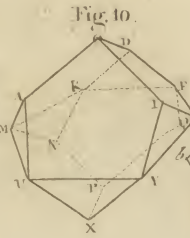
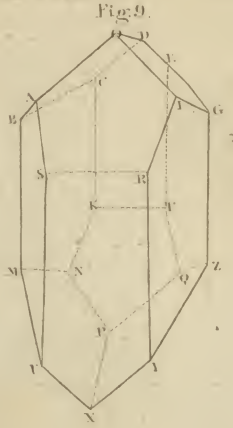
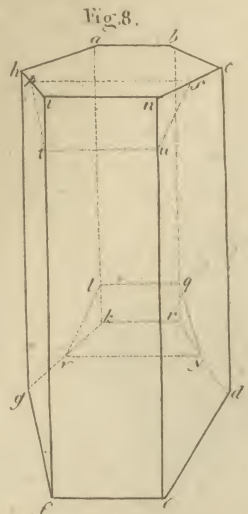
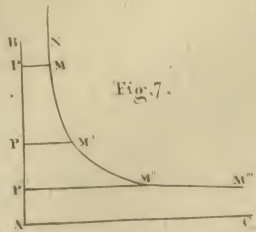


Fig. 3.

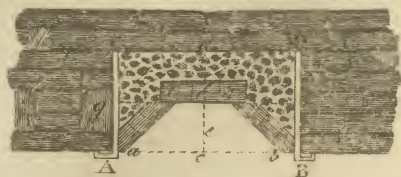


Fig. 5.

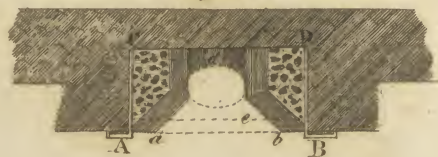


Fig. 8.

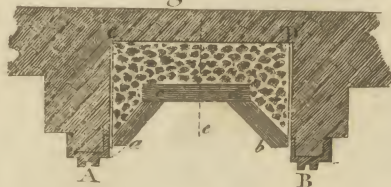


Fig. 4.

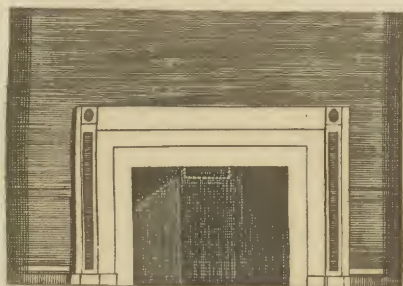


Fig. 7.



Fig. 6.



Scale 1 2 3 4 5 of feet

CRANE

Fig. 1.



Fig. 1.

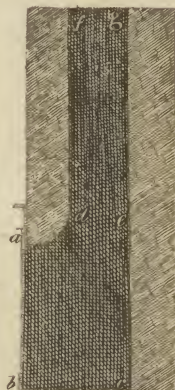


Fig. 2.

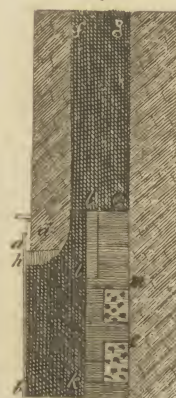


Fig. 2.

Crown,
Cruz.

of box or pear-tree, consisting of a square staff of about three feet long, having each of its faces divided like a line of tangents, and having four cross pieces of unequal lengths to fit on the staff, the halves of these being as the radii to the tangent lines on the faces of the staff.—The instrument was used in taking the altitudes of the celestial bodies at sea.

CROWN, in astronomy, a name given to two constellations, the southern and the northern.

CROWN, in geometry, a plane ring included between two parallel or concentric peripheries of unequal circles.

Crown-Post, is a post in some buildings standing upright in the middle between two principal rafters; and from which proceed struts or braces to the middle of each rafter. It is otherwise called a *king-post*, or *king's-piece*, or *joggle-piece*.

LA CRUZ, an excellent harbour on the north-west coast of America, discovered by the Spaniards in 1779. They were introduced into it by a passage which they called *Bucarelli's Entrance*, and which they placed in 55° 18' N. Lat. and 139° 15' W. Long. from the meridian of Paris. There is no good reason to question the exactness of the latitude of this passage as laid down by the Spaniards; but the editor of Perouse's voyage justly concludes, from the survey made by our celebrated navigator Captain Cook on the coasts adjacent to the entrance of Bucarelli, that this entrance is about 135° 20' to the west of Paris, or very nearly 133° west of Greenwich.

The Spaniards were not long in the harbour of *La Cruz* before they received a visit from the inhabitants in its neighbourhood. Bartering took place. The Indians gave their peltry, and various trifles, for glass beads, bits of old iron, &c. By this traffic the Spaniards were enabled to gain a sufficiently exact knowledge of their genius, of their offensive and defensive arms, of their manufactures, &c.

Their colour is a clear olive; many among them have, however, a perfectly white skin: their countenance is well proportioned in all its parts. They are robust, courageous, arrogant, and warlike.

They clothe themselves in one or two undressed skins (with the fur apparently); these are the skins of otters, of sea-wolves, of benades (a species of deer), of bears, or other animals, which they take in hunting. These dresses cover them from the neck to the middle of the leg; there are, however, many among them who wear boots of smooth skin, resembling English boots, only that those of the Indians open before, and are laced tight with a string. They wear hats woven from the fine bark of trees, the form of which resembles that of a funnel or a cone. At the wrists they have bracelets of copper or iron, or for want of these metals the fins of whales; and round the neck, necklaces of small fragments of bones of fishes and other animals, and even copper collars of the bigness of two fingers. They wear in their ears pendants of mother-of-pearl, or flat pieces of copper, on which is embossed a resin of a topaz colour, and which are accompanied with jet beads. Their hair is long and thick, and they make use of a comb to hold it together in a small queue from the middle to the extremity; a narrow ribbon of coarse linen, woven for this purpose, serves as a ligament. They wear also as a covering a kind of scarf, woven in a particular manner, something more than a yard and a half

Cruz.

long, and about half a yard broad, round which hangs a fringe something more than half a quarter of a yard deep, of which the thread is regularly twisted.

The women give proofs of their modesty and decency by their dress. Their physiognomy is agreeable, their colour fresh, their cheeks vermilioned, and their hair long; they plait it together in one long tress. They wear a long robe of a smooth skin tied round the loins, like that of a nun; it covers them from the neck as low as the feet; the sleeves reach down to the wrists. Upon this robe they put divers skins of otters or other animals to defend themselves from the inclemency of the weather. Better dressed, many of them might dispute charms with the most handsome Spanish women; but dissatisfied with their natural charms, they have recourse to art, not to embellish, but to disfigure themselves. All the married women have a large opening in the under lip, and this opening or orifice is filled up by a piece of wood cut in an oval shape, of which the smallest diameter is almost an inch; the more a woman is advanced in years, the more this curious ornament is extended: it renders them frightful, the old women especially, whose lip, deprived of its wonted spring, and dragged by the weight of this extraordinary jewel, necessarily hangs in a very disagreeable manner. The girls wear only a copper needle, which crosses the lip in the place where the ornament is intended hereafter to be placed.

These Indians in war make use of cuirasses and shoulder pieces of a manufacture like that of the whalebone stays among the Europeans. Narrow boards or scantlings form, in some sort, the woof of the texture, and threads are the warp: in this manner the whole is very flexible, and leaves a free use to the arms for the handling of weapons. They wear round the neck a coarse and large gorget which covers them as high as below the eyes, and their head is defended by a morion, or skull-piece, usually made of the head of some ferocious animal. From the waist downwards, they wear a kind of apron, of the same contexture as their cuirass. Lastly, a fine skin hangs from their shoulders down to the knee. With this armour they are invulnerable to the arrows of their enemies; but thus armed, they cannot change position with so much agility as if they were less burdened.

Their offensive arms are arrows; bows, of which the strings are woven like the large cords of our best musical instruments; lances, four yards in length, tongued with iron; knives, of the same metal, longer than European bayonets, a weapon, however, not very common among them; little axes of flint, or of a green stone, so hard that they cleave the most compact wood without injury to their edge.

The pronunciation of their language is extremely difficult; they speak from the throat, with a movement of the tongue against the palate. The little use the women make of the inferior lip greatly injures the distinctness of their language. The Spaniards could neither pronounce nor write the words which they heard.

From the vivacity of spirit in these Indians, and from their attention amply to furnish the market established in the harbour, it may be concluded that they are pretty laborious. They continually brought stuffs well woven and shaded by various colours, the skins of land and sea wolves, of otters, bears, and other smaller animals;

Cruz.

mals; of these some were raw, and others dressed. There were to be found at this market also coverlets of coarse cloth, shaded with white and brown colours, very well woven, but in small quantities: large ribbons of the same linen which might match with that of the Spanish officers mattresses; skeins of thread such as this cloth was made of; wooden plates or bowls neatly worked; small boats, or canoes, painted in various colours, the figures of which represented heads with all their parts; frogs in wood, nicely imitated, which opened like tobacco boxes, and which they employed to keep their trinkets in: boxes made of small planks, of a cubical form, being three quarters of a yard on each side, with figures well drawn, or carved on the outside, representing various animals; the covers fabricated like Flanders etwees, with rabbeted edges, formed so as to shut into the body of the box; animals in wood, as well those of the earth as of the air; figures of men of the same material, with skull-caps representing the heads of various fierce animals; snares and nets for fishing; copper collars for the neck, and bracelets of iron for the wrist, but which they would not part with except at a very high price; beak-like instruments, from which they drew sounds as from a German flute. The principal officers took such of these merchandizes as were most agreeable to them, and left the remainder to the ships crews.

As the Indians discovered that the Spaniards were very dainty in their fish, they did not let them want for choice: the greatest abundance was in salmon, and a species of sole or turbot three yards and a quarter long, broad and thick in proportion; cod and pilchards were also brought to market, and fishes resembling trout. From all this it may be inferred, that this gulf is full of fish; the banks too are covered with shells.

The quantity of mother-of-pearl that these Indians cut to pieces for making ear-rings awakened the curiosity of the Spaniards: they tried to discover whether these people had not in their possession, or whether their country did not produce pearls, or some precious stones: their researches were fruitless; they only found some stones which they judged to be metallic, and which they carried on board, not having the necessary means for extracting the metal they might contain.

These Indians feed upon fish, fresh or dry, boiled or roasted; herbs and roots which their mountains yielded them, and particularly that which in Spain is called sea parsley; and, lastly, upon the flesh of animals which they take in hunting: the productions of the chase are undoubtedly abundant, seeing the number of dogs they keep for this purpose.

These Indians appeared to the Spaniards to worship the sun, the earliest and most natural of all idolatrous worship; and they paid a decent respect to the remains of their dead. Don Maurelle, one of the Spanish officers, in an expedition round the gulf, found in two islands three dead bodies laid in boxes of a similar form to those which have been described above, though considerably larger, and decked in their furs. These biers were placed in a little hut upon a platform, or raised floor, made of the branches of trees.

The country is very hilly, the mountains are lofty, and their slope extends almost every where to the sea. The soil, limestone; it is nevertheless covered with an impenetrable forest of tall fir trees, very large and very

strait. As these trees cannot strike very deep into the earth, the violence of the wind often tears them up by the roots: they rot and become a light mould, upon which grows a bushy thicket; and in this are found nettles, camomile, wild celery, anise, a species of cabbage, celandine, elder, wormwood, sorrel; and without doubt there are other plants along the rivers.

The Spaniards saw ducks, gulls, divers, kites, ravens, geese, storks, gold-finches, and other little birds unknown to them.

The commerce between the Spaniards and the Indians was quite undisturbed; and so desirous were the latter to obtain iron, cloth, and other stuffs, that they sold their children for broken iron hoops and other wares. The Spaniards in this manner bought three young lads, one from five to six years old, another of four, and the third from nine to ten, not to make slaves, but Christians of them; they hoped besides to derive useful information from them as to the nature of the country and its inhabitants. These youths were so contented in being with the Spaniards, that they hid themselves when their parents came on board, from the apprehension of being again restored to them. Two young girls were also purchased with the same view; one very ugly, seven years of age; the other younger, better made, but sickly, and almost at the gates of death.

At the full and change of the moon, the sea rises in the harbour of La Cruz seventeen feet three inches English; it is then high water at a quarter after 12 at noon: the lowest tides are fourteen feet three inches; the night tides exceed by one foot nine inches those of the day.

CRYSTAL,
CRYSTALLIZATION,

and

Rock-CRYSTAL.

See CRYSTAL and CRYSTALLIZATION, *Encycl.* and CHEMISTRY-*Index* in this Supplement.

CUBIC HYPERBOLA, is a figure expressed by the equation $xy^2 = a$, having two asymptotes, and consisting of two hyperbolas, lying in the adjoining angles of the asymptotes, and not in the opposite angles, like the Apollonian hyperbola; being otherwise called by Newton, in his *Enumeratio Linearum Tertii Ordinis*, an hyperbolismus of a parabola; and is the 65th species of those lines according to him.

Cubic Parabola, a curve of the second order, having two infinite legs tending contrary ways. The curve of this parabola cannot be rectified even by means of the conic sections.

CULLEN (Dr William) was a man to whom physical science is so deeply indebted, that it has often struck us with wonder that no account of him has yet been given to the public, which deserves to be classed with British biography. We know, indeed, that a life of him has been written by an eminent physician well qualified and strongly inclined to do justice to the merits of his revered preceptor; but that life has been withheld from us by him who has certainly the best right to consider himself as the guardian of the Doctor's fame, and who, we have been told, is to enlarge and publish it himself. In this state of things our readers must pardon us for laying before them a very imperfect account of this eminent man, to whom we were ourselves almost strangers. There is a character of him in the periodical publication called *The Bee*, which we shall

Cruz
||
Cullen.

Cullen. shall appropriate to our own use, we are persuaded, with the entire approbation of its author, though sometimes we may express our suspicions that his praise is exaggerated.

Dr William Cullen was born in Lanarkshire, in the west of Scotland, 11th December 1712. His father was for some time chief magistrate of the town of Hamilton; but though a very respectable man, his circumstances were not such as to permit him to lay out much money on the education of his son. William therefore, after serving an apprenticeship to a surgeon apothecary in Glasgow, went several voyages to the West Indies as a surgeon in a trading vessel from London: but of this employment he tired, and settled himself, at an early period of life, as a country surgeon in the parish of Shotts, where he staid a short time practising among the farmers and country people, and then went to Hamilton with a view to practise as a physician, having never been fond of operating as a surgeon.

While he resided near Shotts, it chanced that Archibald Duke of Argyle, who at that time bore the chief political sway in Scotland, made a visit to a gentleman of rank in that neighbourhood. The Duke was fond of literary pursuits, and was then particularly engaged in some chemical researches, which required to be elucidated by experiment. Eager in these pursuits, his Grace, while on this visit, found himself much at a loss for the want of some small chemical apparatus, which his landlord could not furnish: but happily recollecting young Cullen in the neighbourhood, he mentioned him to the Duke as a person who could probably furnish it. He was accordingly invited to dine; was introduced to his Grace,—who was so much pleased with his knowledge, his politeness, and address, that he formed an acquaintance which laid the foundation of all Dr Cullen's future advancement.

The name of Cullen by this time became familiar at every table in that neighbourhood; and thus he came to be known, by character, to the Duke of Hamilton, who then resided, for a short time, in that part of the country: and that nobleman having been suddenly taken ill, the assistance of young Cullen was called in; which proved a fortunate circumstance in serving to promote his advancement to a station in life more suited to his talents than that in which he had hitherto moved.

The character of the Douglasses, of which name the family of Hamilton now forms a principal branch, has always been somewhat of the same stamp with that of the rising Cullen. Genius, benevolence, frankness, and conviviality of disposition, have been, with them in general, very prominent features; and if to that be added a spirit of frolic and dissipation, these will be accounted as only natural consequences of those youthful indulgences that spring from an excess of wealth at an early period of life, and the licence allowed to people of elevated rank. The Duke was therefore highly delighted with the sprightly character and ingenious conversa-

tion of his new acquaintance. Receiving instruction from him in a much more pleasing, and an infinitely easier way than he had ever before obtained, the conversation of Cullen proved highly interesting to his Grace.—No wonder then that he soon found means to get his favourite Doctor, who was already the esteemed acquaintance of the man through whose hands all preferments in Scotland were obliged to pass, appointed to a place in the university of Glasgow, where his singular talents for discharging the duties of the station he now occupied soon became very conspicuous (A).

During his residence in the country, however, several important incidents occurred, that ought not to be passed over in silence. It was during this time that was formed a connection in business in a very humble line between two men, who became afterwards eminently conspicuous in much more exalted stations. William, afterwards Doctor, Hunter, the famous lecturer on anatomy in London, was a native of the same part of the country; and not being in affluent circumstances more than Cullen, these two young men, stimulated by the impulse of genius to prosecute their medical studies with ardour, but thwarted by the narrowness of their fortune, entered into a copartnership business as surgeons and apothecaries in the country. The chief end of their contract being to furnish the parties with the means of prosecuting their medical studies, which they could not separately so well enjoy, it was stipulated, that one of them alternately should be allowed to study in what college he inclined, during the winter, while the other should carry on the business in the country for their common advantage. In consequence of this agreement, Cullen was first allowed to study in the university of Edinburgh for one winter; but when it came to Hunter's turn next winter, he, preferring London to Edinburgh, went thither. There his singular neatness, in dissecting, and uncommon dexterity in making anatomical preparations, his assiduity in study, his mildness of manner, and pliability of temper, soon recommended him to the notice of Dr Douglass, who then read lectures upon anatomy and midwifery there; who engaged Hunter as an assistant, and whose chair he afterwards filled with so much honour to himself and satisfaction to the public.

Thus was dissolved, in a premature manner, a copartnership perhaps of as singular a kind as is to be found in the annals of literature: nor was Cullen a man of that disposition to let any engagement with him prove a bar to his partner's advancement in life. The articles were freely departed from by him; and Cullen and Hunter ever after kept up a very cordial and friendly correspondence; though, it is believed, they never from that time had a personal interview.

During the time that Cullen practised as a country surgeon and apothecary, he formed another connection of a more permanent kind, which, happily for him, was not dissolved till a very late period of his life. With

(A) It was not, however, solely to the favour of these two great men that Cullen owed his literary fame. He was recommended to the notice of men of science in a way still more honourable to himself. The disease of the Duke of Hamilton having resisted the effect of the first applications, Dr Clarke was sent for from Edinburgh; and he was so much pleased with every thing that Cullen had done, that he became his eulogist upon every occasion. Cullen never forgot this; and when Clarke died, gave a public oration in his praise in the University of Edinburgh; which, it is believed, was the first of the kind in this country.

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the ardour of disposition he possessed, it cannot be supposed he beheld the fair sex with indifference. Very early in life he took a strong attachment to an amiable woman, a Miss Johnston, daughter to a clergyman in that neighbourhood, nearly of his own age, who prevailed on to join with him in the sacred bonds of wedlock, at a time when he had nothing else to recommend him to her except his person and dispositions; for as to riches and possessions he had little of these to boast of. She was beautiful, had great good sense, equanimity of temper, an amiable disposition, and elegance of manners, and brought with her a little money, which, though it would be accounted nothing now, was something in those days to one in his situation in life. After giving to him a numerous family, and participating with him the changes of fortune which he experienced, she peacefully departed this life in summer 1786.

In the year 1746, Cullen, who had now taken the degree of doctor in physic, was appointed a lecturer in chemistry in the university of Glasgow: and in the month of October began his lectures in that science. His singular talents for arrangement, his distinctness of enunciation, his vivacity of manner, and his knowledge of the science he taught, rendered his lectures interesting to the students to a degree that had been till then unknown at that university. He became, therefore, in some measure, adored by the students. The former professors were eclipsed by the brilliancy of his reputation; and he had to experience all those little rubs that envy and disappointed ambition naturally threw in his way. Regardless, however, of these secret shagreens, he pressed forward with ardour in his literary career; and, supported by the favour of the public, he consoled himself for the contumely he met with from a few individuals. His practice as a physician increased from day to day; and a vacancy having occurred in the year 1751, he was then appointed by the king professor of medicine in that university. This new appointment served only to call forth his powers, and to bring to light talents that it was not formerly known he possessed; so that his fame continued to increase.

As, at that period, the patrons of the university of Edinburgh were constantly on the watch for the most eminent medical men to support the rising fame of the college, their attention was soon directed towards Cullen; who, on the death of Dr Plumber, professor of chemistry, was, in 1756, unanimously invited to accept the vacant chair. This invitation he accepted: and having resigned all his employments in Glasgow, he began his academical career in Edinburgh in the month of October of that year; and there he resided till his death.

If the admission of Cullen into the university of Glasgow gave great spirit to the exertions of the students, this was still, if possible, more strongly felt in Edinburgh. Chemistry, which had been till that time of small account in that university, and was attended to by very few of the students, instantly became a favourite study; and the lectures upon that science were more frequented than any others in the university, anatomy alone excepted. The students, in general, spoke of Cullen with the rapturous ardour that is natural to youth when they are highly pleased. These eulogiums appeared extravagant to moderate men, and could not fail to prove disgusting to his colleagues. A party was

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formed among the students for opposing this new favourite of the public; and these students, by misrepresenting the doctrines of Cullen to others who could not have an opportunity of hearing these doctrines themselves, made even some of the most intelligent men in the university think it their duty publicly to oppose these imaginary tenets. The ferment was thus augmented; and it was some time before the professors discovered the arts by which they had been imposed upon, and universal harmony restored.

During this time of public ferment, Cullen went steadily forward, without taking any part himself in these disputes. He never gave ear to any tales respecting his colleagues, nor took any notice of the doctrines they taught: That some of their unguarded strictures might at times come to his knowledge, is not impossible; but if they did, they seemed to make no impression on his mind.

These attempts of a party of students to lower the character of Cullen on his first outset in the university of Edinburgh having proved fruitless, his fame as a professor, and his reputation as a physician, became more and more respected every day. Nor could it well be otherwise: Cullen's professional knowledge was always great, and his manner of lecturing singularly clear and intelligible, lively and entertaining; and to his patients, his conduct in general as a physician was so pleasing, his address so affable and engaging, and his manner so open, so kind, and so little regulated by pecuniary considerations, that it was impossible for those who had occasion to call once for his medical assistance, ever to be satisfied on any future occasion without it. He became the friend and companion of every family he visited; and his future acquaintance could not be dispensed with.

But if Dr Cullen in his public capacity deserved to be *admired*, in his private capacity by his students he deserved to be *adored*. His conduct to them was so attentive, and the interest he took in the private concerns of all those students who applied to him for advice, was so cordial and so warm, that it was impossible for any one who had a heart susceptible of generous emotions, not to be enraptured with a conduct so uncommon and so kind. Among ingenuous youth, gratitude easily degenerates into rapture—into respect nearly allied to adoration. Those who advert to this natural construction of the human mind, will be at no loss to account for that popularity that Cullen enjoyed—a popularity, that those who attempt to weigh every occurrence by the cool standard of *reason* alone, will be inclined to think excessive. It is fortunate, however, that the bulk of mankind will ever be influenced in their judgment, not less by feelings and affections than by the cold and phlegmatic dictates of *reason*. The adoration which generous conduct excites, is the reward which nature hath appropriated exclusively to disinterested beneficence. This was the secret charm that Cullen ever carried about with him, which fascinated such numbers of those who had intimate access to him. This was the power which his envious opponents never could have an opportunity of feeling.

The general conduct of Cullen to his students was thus. With all such as he observed to be attentive and diligent, he formed an early acquaintance, by inviting them by twos, by threes, or by fours at a time, to sup-

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the most engaging ease, and freely entering with them on the subject of their studies, their amusements, their difficulties, their hopes, and future prospects. In this way he usually invited the whole of his numerous class, till he made himself acquainted with their abilities, their private character, and their objects of pursuit. Those among them whom he found most assiduous, best disposed, or the most friendless, he invited the most frequently, till an intimacy was gradually formed, which proved highly beneficial to them. Their doubts, with regard to their objects of study, he listened to with attention, and solved with the most obliging condescension. His library, which consisted of an excellent assortment of the best books, especially on medical subjects, was at all times open for their accommodation; and his advice, in every case of difficulty to them, they always had it in their power most readily to obtain. They seemed to be his family; and few persons of distinguished merit have left the university of Edinburgh in his time, with whom he did not keep up a correspondence till they were fairly established in business. By these means he came to have a most accurate knowledge of the state of every country, with respect to practitioners in the medical line; the only use he made of which knowledge was, to direct students in their choice of places, where they might have an opportunity of engaging in business with a reasonable prospect of success. Many, very many, able men has he thus put into a good line of business where they never could have thought of it themselves; and they are now reaping the fruits of this beneficent foresight on his part.

Nor was it in this way only that he befriended the students at the university of Edinburgh. Possessing a benevolence of mind that made him ever think first of the wants of others, and recollecting the difficulties that he himself had had to struggle with in his younger days, he was at all times singularly attentive to their pecuniary concerns. From his general acquaintance among the students, and the friendly habits he was on with many of them, he found no difficulty in discovering those among them who were rather hampered circumstances, without being obliged to hurt their delicacy in any degree. To such persons, when their habits of study admitted of it, he was peculiarly attentive. They were more frequently invited to his house than others; they were treated with more than usual kindness and familiarity; they were conducted to his library, and encouraged by the most delicate address to borrow from it freely whatever books he thought they had occasion for: and as persons in these circumstances were usually more shy in this respect than others, books were sometimes pressed upon them as a sort of constraint, by the Doctor insisting to have their opinion of such or such passages they had not read, and desiring them to carry the book home for that purpose. He, in short, behaved to them rather as if he courted their company, and stood in need of their acquaintance than they of his. He thus raised them in the opinion of their acquaintance to a much higher degree of estimation than they could otherwise have obtained; which, to people whose minds were depressed by penury, and whose sense of honour was sharpened by the consciousness of an inferiority of a certain kind, was singularly engaging. Thus they were inspired with a secret sense of dignity, which elevated their minds, and excited an

uncommon ardour of pursuit, instead of that melancholy inactivity which is so natural in such circumstances, and which too often leads to despair. Nor was he less delicate in the manner of supplying their wants, than attentive to discover them. He often found out some polite excuse for refusing to take payment for a first course, and never was at a loss for one to an after course. Before they could have an opportunity of applying for a ticket, he would sometimes lead the conversation to some subject that occurred in the course of his lectures; and as his lectures were never put in writing by himself, he would sometimes beg the favour to see their notes, if he knew they had been taken with attention, under a pretext of assisting his memory. Sometimes he would express a wish to have their opinion of a particular part of his course, and presented them with a ticket for that purpose; and sometimes he refused to take payment, under the pretext that they had not received his full course the preceding year, some part of it having been necessarily omitted for want of time, which he meant to include in this course. By such delicate address, in which he greatly excelled, he took care to fore-run their wants. Thus he not only gave them the benefit of his own lectures, but by refusing to take their money, he also enabled them to attend those of others that were necessary to complete their course of studies. These were particular devices he adopted to individuals to whom economy was necessary; but it was a general rule with him, never to take money from any student for more than two courses of the same set of lectures, permitting him to attend these lectures as many years longer as he pleased *gratis*.

He introduced another general rule into the university, that was dictated by the same principle of disinterested beneficence, that ought not to be here passed over in silence. Before he came to Edinburgh, it was the custom of medical professors to accept of fees for their medical assistance, when wanted, even from medical students themselves, who were perhaps attending the professor's own lectures at the time. But Cullen never would take fees as a physician from any student at the university, though he attended them, when called in as a physician, with the same assiduity and care as if they had been persons of the first rank, who paid him most liberally. This gradually induced others to adopt a similar practice; so that it is now become a general rule for medical professors to decline taking any fees when their assistance is necessary to a student. For this useful reform, with many others, the students of the university of Edinburgh are solely indebted to the liberality of Dr Cullen.

The first lectures which Cullen delivered in Edinburgh were on chemistry; and for many years he also gave clinical lectures on the cases which occurred in the Royal Infirmary. In the month of February 1763, Dr Alston died, after having begun his usual course of lectures on the *materia medica*; and the magistrates of Edinburgh, as patrons of that professorship in the university, appointed Dr Cullen to that chair, requesting that he would finish the course of lectures that had been begun for that season. This he agreed to do; and though he was under a necessity of going on with the course in a few days after he was nominated, he did not once think of reading the lectures of his predecessor, but resolved to deliver a new course entirely his own.

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The popularity of Cullen at this time may be guessed at by the increase of new students who came to attend his course in addition to the eight or ten who had entered to Dr Allston. The new students exceeded 100. An imperfect copy of these lectures, thus fabricated in haste, having been published, the Doctor thought it necessary to give a more correct edition of them in the latter part of his life. But his faculties being then much impaired, his friends looked in vain for those striking beauties that characterised his literary exertions in the prime of life.

Some years afterwards, on the death of Dr White, the magistrates once more appointed Dr Cullen to give lectures on the theory of physic in his stead. And it was on that occasion Dr Cullen thought it expedient to resign the chemical chair in favour of Dr Black, his former pupil, whose talents in that department of science were then well known, and who filled the chair till his death with great satisfaction to the public*. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applause on the practice of physic, Dr John Gregory (whose name can never be mentioned by any one who had the pleasure of his acquaintance without the warmest tribute of a grateful respect) having become a candidate for this place along with Dr Cullen, a sort of compromise took place between them; by which they agreed each to give lectures alternately on the theory and on the practice of physic during their joint lives, the longest survivor being allowed to hold either of the classes he should incline. In consequence of this agreement, Dr Cullen delivered the *first* course of lectures on the practice of physic in winter 1766, and Dr Gregory succeeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the students than this. Both these men possessed great talents, though of a kind extremely dissimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and respected the talents of the other. They co-operated, therefore, in the happiest manner, to enlarge the understanding, and to forward the pursuits of their pupils. Unfortunately this arrangement was soon destroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a sudden and unforeseen event. After this time, Cullen continued to give lectures on the practice of physic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

In drawing the character of Dr Cullen, Dr Anderson, to whom we are indebted for this sketch, observes, that in scientific pursuits men may be arranged into two grand classes, which, though greatly different from each other in their extremes, yet approximate at times so near as to be blended indiscriminately together; those who possess a talent for detail, and those who are endowed with the faculty of arrangement. The first may be said to view objects individually as through a microscope. The field of vision is confined; but the objects included within that field, which must usually be considered singly and apart from all others, are seen with a wondrous degree of accuracy and distinctness. The other takes a sweeping view of the universe at large, considers every object he perceives not individually, but as a part of one harmonious whole: His mind

is therefore not so much employed in examining the separate parts of this individual object, as in tracing its relations, connections, and dependencies, on those around it.—Such was the turn of Cullen's mind. The talent for arrangement was that which peculiarly distinguished him from the ordinary class of mortals; and this talent he possessed perhaps in a more distinguished degree than any other person of the age in which he lived. Many persons exceeded him in the minute knowledge of particular departments, who, knowing this, naturally looked upon him as their inferior; but possessing not at the same time that glorious faculty, which, “with an eye wide roaming, glances from the earth to heaven,” or the charms which this talent can infuse into congenial minds, felt disgust at the pre-eminence he obtained, and astonishment at the means by which he obtained it. An Aristotle and a Bacon have had their talents in like manner appreciated; and many are the persons who can neither be exalted to sublime ideas with Homer, nor ravished with the natural touches of a Shakespeare. Such things are wisely ordered, that every department in the universe may be properly filled by those who have talents exactly suited to the task assigned them by heaven.

Had Cullen, however, possessed the talents for arrangement alone, small would have been his title to that high degree of applause he has attained. Without a knowledge of *facts*, a talent for arrangement produces nothing but chimeras; without materials to work upon, the structures which an over-heated imagination may rear up are merely “the baseless fabric of a vision.” No man was more sensible of the justness of this remark than Dr Cullen, and few were at greater pains to avoid it. His whole life, indeed, was employed, almost without interruption, in collecting facts. Whether he was reading, or walking, or conversing, these were continually falling into his way. With the keen perception of an eagle, he marked them at the first glance; and without stopping at the time to examine them, they were stored up in his memory, to be drawn forth as occasion required, to be confronted with other facts that had been obtained after the same manner, and to have their truth ascertained, or their falsity proved, by the evidence which should appear when carefully examined at the impartial bar of justice. Without a memory retentive in a singular degree, this could not have been done; but so very extraordinary was Dr Cullen's memory, that till towards the very decline of life, there was scarcely a fact that had ever occurred to him which he could not readily recollect, with all its concomitant circumstances, whenever he had occasion to refer to it. It was this faculty which so much abridged his labour in study, and enabled him so happily to avail himself of the labour of others in all his literary speculations. He often reaped more by the conversation of an hour than another man would have done in whole weeks of laborious study.

In his lectures, Dr Cullen never attempted to read. His lectures were delivered *viva voce*, without having been previously put into writing, or thrown into any particular arrangement. The vigour of his mind was such, that nothing more was necessary than a few short notes before him, merely to prevent him from varying from the general order he had been accustomed to observe. This gave to his discourses an ease, a vacancy,

* See Black, death with great satisfaction to the public*. Soon after, on the death of Dr Rutherford, who for many years had given lectures with applause on the practice of physic, Dr John Gregory (whose name can never be mentioned by any one who had the pleasure of his acquaintance without the warmest tribute of a grateful respect) having become a candidate for this place along with Dr Cullen, a sort of compromise took place between them; by which they agreed each to give lectures alternately on the theory and on the practice of physic during their joint lives, the longest survivor being allowed to hold either of the classes he should incline. In consequence of this agreement, Dr Cullen delivered the *first* course of lectures on the practice of physic in winter 1766, and Dr Gregory succeeded him in that branch the following year. Never perhaps did a literary arrangement take place that could have proved more beneficial to the students than this. Both these men possessed great talents, though of a kind extremely dissimilar. Both of them had certain failings or defects, which the other was aware of, and counteracted. Each of them knew and respected the talents of the other. They co-operated, therefore, in the happiest manner, to enlarge the understanding, and to forward the pursuits of their pupils. Unfortunately this arrangement was soon destroyed by the unexpected death of Dr Gregory, who was cut off in the flower of life by a sudden and unforeseen event. After this time, Cullen continued to give lectures on the practice of physic till a few months before his death, which happened on the 5th of February 1790, in the 77th year of his age.

Cullen. vacuity, a variety, and a force, that are rarely to be met with in academical discourses. His lectures, by consequence, upon the same subject were never exactly the same. Their general tenor indeed was not much varied; but the particular illustrations were always new, well suited to the circumstances that attracted the general attention of the day, and were delivered in the particular way that accorded with the cast of mind the prelector found himself in at the time. To these circumstances must be ascribed that energetic artless elocution, which rendered his lectures so generally captivating to his hearers. Even those who could not follow him in those extensive views his penetrating mind glanced at, or who were not able to understand those apt allusions to collateral objects which he could only rapidly point at as he went along, could not help being warmed in some measure by the vivacity of his manner. But to those who could follow him in his rapid career, the ideas he suggested were so numerous, the views he laid open were so extensive, and the objects to be attained were so important—that every active faculty of the mind was roused; and such an ardour of enthusiasm was excited in the prosecution of study, as appeared to be perfectly inexplicable to those who were merely unconcerned spectators. In consequence of this unshackled freedom in the composition and delivery of his lectures, every circumstance was in the nicest unison with the tone of voice and expression of countenance, which the particular cast of mind he was in at the time inspired. Was he joyous, all the figures introduced for illustration were fitted to excite hilarity and good humour: was he grave, the objects brought under view were of a nature more solemn and grand: and was he peevish, there was a peculiarity of manner in thought, in word, and in action, which produced a most striking and interesting effect. The languor of a nerveless uniformity was never experienced, nor did an abortive attempt to excite emotions that the speaker himself could not at the time feel, ever produce those discordant ideas which prove disgusting and unpleasing.

It would seem as if Dr Cullen had considered the proper business of a preceptor to be that of putting his pupils into a proper train of study, so as to enable them to prosecute those studies at a future period, and to carry them on much farther than the short time allowed for academical selections would admit. He did not, therefore, so much strive to make those who attended his lectures deeply versed in the particular details of objects, as to give them a general view of the whole subject; to shew what had been already attained respecting it; to point out what remained yet to be discovered; and to put them into a train of study that should enable them at a future period, to remove those difficulties that had hitherto obstructed our progress; and thus to advance of themselves to farther and farther degrees of perfection. If these were his views, nothing could be more happily adapted to them than the mode he invariably pursued. He first drew, with the striking touches of a master, a rapid and general outline of the subject, by which the whole figure was seen at once to start boldly from the canvas, distinct in all its parts, and unmixed with any other object. He then began anew to retrace the picture, to touch up the lesser parts, and to finish the whole in as perfect a manner as the state of our knowledge at the time would permit.

Cullen. Where materials were wanting, the picture there continued to remain imperfect. The wants were thus rendered obvious; and the means of supplying these were pointed out with the most careful discrimination. The student, whenever he looked back to the subject, perceived the defects; and his hopes being awakened, he felt an irresistible impulse to explore that hitherto untrodden path which had been pointed out to him, and fill up the chasm which still remained. Thus were the active faculties of the mind most powerfully excited; and instead of labouring himself to supply deficiencies that far exceeded the power of any one man to accomplish, he set thousands at work to fulfil the task, and put them into a train of going on with it, when he himself should be gone to that country “from whose dread bourne no traveller returns.”

It was to these talents, and to this mode of applying them, that Dr Cullen owed his celebrity as a professor; and it was in this manner that he has perhaps done more towards the advancement of science than any other man of his time, though many individuals might perhaps be found who were more deeply versed in the particular departments he taught than he himself was. Chemistry, which was before his time a most disgusting pursuit, was by him rendered a study so pleasing, so easy, and so attractive, that it is now prosecuted by numbers as an agreeable recreation, who but for the lights that were thrown upon it by Cullen and his pupils, would never have thought of engaging in it at all; though perhaps they never heard of Cullen's name, nor have at this time the most distant idea that they owe any obligations to him; and the same may be said of the other branches of science which he taught.

According to a man who knew him well, there are three things which eminently distinguished Cullen as a professor. “The energy of his mind, by which he viewed every subject with ardour, and combined it immediately with the whole of his knowledge.

“The scientific arrangement which he gave to his subject, by which there was a *lucidus ordo* to the dullest scholar. He was the first person in this country who made chemistry cease to be a chaos.

“A wonderful art of interesting the students in every thing which he taught, and of raising an emulative enthusiasm among them.”

We are well aware that this character will by many be deemed an extravagant panegyric; but having no opportunity of judging for ourselves, we would rather adopt from others an extravagant panegyric than an unmerited censure. Dr Anderson himself admits that Cullen's character was far from perfect; and, in the opinion of most other men with whom we have conversed on the subject, and who were at the same time qualified to form an estimate of his mental powers, his imagination was not balanced by his judgment. Hence the common remark in the university of Edinburgh, that Dr Cullen was more successful in demolishing the theories of others than in giving stability to those which were reared by himself.

Dr Cullen's external appearance, though striking and not unpleasing, was not elegant. His countenance was expressive, and his eye in particular remarkably lively, and at times wonderfully penetrating. In his person he was tall and thin, stooping very much about the shoulders. When he walked, he had a contemplative look,
and

Curfeu
||
Cuffo.

and did not seem much to regard the objects around him.

CURFEU BELL (see **CURFEW**, *Encycl.*), called in the law Latin of the middle ages *ignitegium* or *pyritegium*, and in French, *cuvre-feu*—was a signal for all persons to extinguish their fires at a certain hour. In those ages people made fires in their houses in a hole or pit in the centre of the floor, under an opening formed in the roof; and when the fire was burnt out, or the family went to bed, the hole was shut by a cover of wood or of earth. This practice still prevails among the cottagers in some parts of Scotland, and we doubt not of other countries. In the dark ages, when all ranks of people were turbulent, a law was almost everywhere established, that the fire should be extinguished at a certain time in the evening; that the cover should be put over the fire-place; and that all the family should retire to rest, or at least keep within doors. The time when this ought to be done was signified by the ringing of a bell, called therefore the *curfeu-bell* or *ignitegium*. The law of William the Conqueror, which introduced this practice into England, as has been mentioned in the *Encyclopædia*, was abolished by Henry I. in 1100.

The ringing of the curfeu-bell gave rise to the prayer-bell, as it is called, which is still retained in some Protestant countries. Pope John XXIII. with a view to avert certain apprehended misfortunes, which rendered his life uncomfortable, gave orders, that every person, on hearing the *ignitegium*, should repeat the *Ave Maria* three times. When the appearance of a comet, and a dread of the Turks, afterwards alarmed all Christendom, Pope Calixtus III. increased these periodical times of prayer, by ordering the prayer-bell to be rung also at noon. *Beckmann's History of Inventions.*

CURVE OF EQUABLE APPROACH. It was first proposed by Leibnitz, namely, to find a curve, down which a body descending by the force of gravity shall make equal approaches to the horizon in equal portions of time. It has been found by Bernoulli and others, that the curve is the second cubical parabola, placed with its vertex uppermost, and which the descending body must enter with a certain determinate velocity. Varignon rendered the question general for any law of gravity, by which a body may approach towards a given point by equal spaces in equal times. And Maupertuis also resolved the problem in the case of a body descending in a medium which resists as the square of the velocity.

CUSSO, or **ΒΑΝΚΣΙΑ ΑΒΥΣΣΙΝΙΚΑ**, is a beautiful and useful tree, indigenous to the high country of Abyssinia. At least Mr Bruce, who has given of it the only description which we have seen, says that he never saw it in any other part of Asia or Africa. It seldom grows above 20 feet high, very rarely straight, generally crooked or inclined. Its leaf, which is of a deep unvarnished green, having the fore part covered with soft hair or down, is about 2½ inches long, divided by a strong rib into two unequal divisions, of which the upper is broader and larger than the lower. It is more indented than even the nettle leaf, which it in some measure resembles, only the leaf of the *Cusso* is narrower and longer.

Those leaves grow two and two upon a branch, having between each two the rudiments of two pair of leaves, which probably are *deciduous*; but the branch is terminated with a single leaf or *stipula* at the point. The end of this stalk is broad and strong, like that of

a palm branch. It is not solid like the gerid of the date tree, but opens in the part that is without leaves about an inch and a half from the bottom, and out of this aperture proceeds the flower. There is a round stalk, bare for about an inch and a quarter, from which proceed crooked branches with single flowers attached to their ends; the stalk that carries these proceeds out of every crook or geniculation. The whole cluster of flowers has very much the shape of a cluster of grapes; the stalks which support it resemble the stalks of the grape; and a very few small leaves are scattered through the cluster of flowers.

“The calyx or flower cup is of a *greenish* colour, tinged with purple; when fully blown it is altogether of a deep red or purple; the corolla is *white*, and consists of five petals; in the midst is a short pistil with a round head, surrounded by eight stamina, of the same form, loaded with yellow farina. The cup consists of five petals, which much resemble another flower; they are rounded at the top, and nearly of an equal breadth every way. The seed is very small, smaller than even the semen fantonicum; and being likewise very bitter it is used in Abyssinia as a vermifuge. From its smallness, however, and its being very easily shed, no great quantity of it is ever gathered, and therefore the flower is often substituted in its stead. The Abyssinians, says our author, of both sexes, and at all ages, are troubled with the sort of worm called *ascarides*, of which every individual evacuates a large quantity once a-month. The method of promoting these evacuations is by infusing a handful of dry *cusso* flowers in about two English quarts of bouza, or the beer they make of teff (see **TEFF**, *Encycl.*), and after it has been steeped all night, the next morning it is fit for use.

“The bark of the tree is smooth, of a yellowish white, interspersed with brown streaks, which pass through the whole body of the tree. It is not firm or hard, but rather stringy and reedy. On the upper part, before the first branch of leaves set out, are rings round the trunk, of small filaments of the consistence of horse hair: these are generally fourteen or sixteen in number, and are a very remarkable characteristic belonging to the tree.”

From this description, which, it must be confessed, is not remarkable for perspicuity, and from an inspection of the figure which Mr Bruce has given of the *cusso*, we are inclined to rank it with the palms, as a new genus, nearest to the *caryota*.

CUVETTE, or **CUNETTE**, in fortification, is a kind of ditch within a ditch, being a pretty deep trench, about four fathoms broad, sunk and running along the middle of the great dry ditch, to hold water; serving both to keep off the enemy and prevent him from mining.

CYCLE OF INDICATION, is a series of 15 years, returning constantly around like the other cycles, and commenced from the third year before Christ; whence it happens that if 3 be added to any given year of Christ, and the sum be divided by 15, what remains is the year of the indication.

CYCLOID (see *Encycl.*) is a curve, which is thus generated: Suppose a wheel or circle to roll along a straight line till it has completed just one revolution; a nail or point in that part of the circumference of the circle, which at the beginning of the motion touches the straight line, will, at the end of the revolution, have described on a vertical plane a cycloid.

DAGELET,

Cuvette
||
Cycloid.

D.

Dagelet,
Dairy.

DAGELET, the name given by *La Perouse*, the celebrated though unfortunate navigator, to an island on the coast of Corea (see *COREA*, *Encycl.*), which he discovered in the year 1787. It is little more than three leagues in circumference; and our author almost made its circuit at the distance of a mile without finding bottom. This small spot is very steep, but covered with the finest trees from the sea-shore to the summit. A rampart of bare rock, like a wall, encircles the whole outline of it, with the exception of seven little sandy creeks, where it is possible to land. In these creeks the Frenchmen saw upon the stocks some boats of a construction altogether Chinese; but the sight of their ships frightened the workmen, who fled from their dock-yard into the wood, which was not more than fifty paces distant. As a few huts were seen, but neither villages nor cultivation, *La Perouse* concluded that the island is without inhabitants, and that the men whom he saw at work were Corean carpenters, who during the summer months go with provision to Dagelet for the purpose of building boats, which they sell upon the continent. He places the north-east point of this island in Lat. 37°. 25' and E. Long. 129°. 2'. from Paris.

DAIRY is a word which signifies sometimes the art of making various kinds of food from milk; sometimes the place where milk is manufactured; and sometimes the management of a milk-farm. On the *dairy*, in the first and second of these senses, enough has been said in the *Encyclopædia* under the titles *BUTTER*, *CHEESE*, and *DAIRY*; on the management of a milk farm that work contains nothing.

When a dairy is established, the undertaker may sometimes think it his interest to obtain the greatest possible quantity of produce; sometimes it may be more beneficial for him to have it of the finest quality; and at other times it may be necessary to have both these objects in view, the one or the other in a greater or less proportion: it is therefore of importance that he should know how he may accomplish the one or the other of these purposes in the easiest and most direct manner.

To be able to convert his milk to the highest possible profit in every case, he ought to be fully acquainted with every circumstance respecting the manufacture both of butter and of cheese; as it may in some cases happen, that a certain portion of that milk may be more advantageously converted into butter than into cheese, while another portion of it would return more profit if made into cheese.

The first thing to be adverted to, in an undertaking of this nature, is to choose cows of a proper sort. Among this class of animals, it is found, by experience,

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that some kinds give milk of a much thicker consistence and richer quality than others; nor is this richness of quality necessarily connected with the smallness of the quantity yielded by cows of nearly an equal size; it therefore behoves the owner of a dairy to be peculiarly attentive to this circumstance. In judging of the value of a cow, it ought rather to be the quantity and the quality of the cream produced from the milk of the cow, in a given time, than the quantity of the milk itself: this is a circumstance that will be shewn hereafter to be of more importance than is generally imagined. The small cows of the Alderney breed afford the richest milk hitherto known; but individual cows in every country may be found, by a careful selection, that afford much thicker milk than others; these therefore ought to be searched for with care, and their breed reared with attention, as being peculiarly valuable.

Few persons who have had any experience at all in the dairy, can be ignorant, however, that in comparing the milk of two cows, to judge of their respective qualities, particular attention must be paid to the time that has elapsed since their calving; for the milk of the same cow is always thinner soon after calving than it is afterwards; as it gradually becomes thicker, though generally less in quantity, in proportion to the time since the cow has calved. The colour of the milk, soon after calving, is richer than it is afterwards; but this, especially for the first two weeks, is a faulty colour that ought not to be coveted.

To make the cows give abundance of milk, and of a good quality, they must at all times have plenty of food. Grass is the best food yet known for this purpose, and that kind of grass which springs up spontaneously on rich dry soils is the best of all. If the temperature of the climate be such as to permit the cows to graze at ease throughout the day, they should be suffered to range on such pastures at freedom; but if the cows are so much incommoded by the heat as to be prevented from eating through the day, they ought in that case to be taken into cool shades for protection; where, after allowing them a proper time to ruminate, they should be supplied with abundance of green food, fresh-cut for the purpose, and given to them by hand frequently, in small quantities, fresh and fresh, so as to induce them to eat it with pleasure. When the heat of the day is over, and they can remain abroad with ease, they may be again turned into the pasture, where they should be allowed to range with freedom all night, during the mild weather of summer.

Cows, if abundantly fed, should be milked three times a-day, during the whole of the summer season (A); in

30

the

(A) If cows be milked only twice in the day (24 hours), while they have abundance of succulent food, they will yield a much smaller quantity of milk, in the same time, than if they be milked three times. Some attentive observers think a cow, in these circumstances, will give nearly as much milk at each time, if milked three times, as if she were milked only twice. This fact, however, has not, that we know of, been ascertained by experiment. There can be no doubt but they give more, how much more is not ascertained; nor, whether it would be advantageous, in any case, to milk them four times, or oftener; nor, what effect frequent milking produces on the quality of the milk.

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the morning early, at noon, and in the evening, just before night-fall. In the choice of persons for milking the cows, great caution should be employed; for if that operation be not carefully and properly performed, not only the quantity of the produce of the dairy will be greatly diminished, but its quality also will be very much debased; for if all the milk be not thoroughly drawn from a cow when she is milked, that portion of milk which is left in the udder seems to be gradually absorbed into the system, and Nature generates no more than to supply the waste of what has been taken away. If this lessened quantity be not again thoroughly drawn off, it occasions a yet farther diminution of the quantity of milk generated; and thus it may be made to proceed, in perpetual progression from little to less, till none at all is produced. In short, this is the practice in all cases followed, when it is meant to allow a cow's milk to dry up entirely, without doing her hurt. In this manner, therefore, the profits of a dairy might be wonderfully diminished; so that it much behoves the owner of it to be extremely attentive to this circumstance, if he wishes to avoid ruin. It ought to be a rule without an exception, never to allow this important department to be entrusted, without controul, to the management of hired servants (b). Its importance will be still more manifest from what follows.

It is to Dr James Anderson that we are indebted for these judicious observations, as well as for the following aphorisms which, though they may be in part known to attentive housewives, he has reason to believe are not commonly adverted to as their importance deserves.

Aphorism
1.

"Of the milk that is drawn from any cow at one time, that which comes off at the first is always thinner, and of a much worse quality, than that which comes afterwards; and the richness goes on continually increasing to the very last drop that can be drawn from the udder at that time."

Few persons are ignorant that the milk which is last of all taken from the cow at milking (in this country called *stroakings*) is richer than the rest of the milk; but fewer still are aware of the greatness of the disproportion between the quality of the first and the last drawn milk, from the same cow, at one milking. The following facts (says our author) respecting this circumstance were ascertained by me many years ago, and have been confirmed by many subsequent experiments and observations.

Having taken several large tea-cups, exactly of the same size and shape, one of these tea-cups was filled at the beginning of the milking, and the others at regular intervals, till the last, which was filled with the dregs of the *stroakings*. These cups were then weighed, the weight of each having been settled, so as to ascertain that the quantity of milk in each was precisely the same; and from a great number of experiments, frequently repeated with many different cows, the result was in all cases as follows:

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The quantity of cream obtained from the first-drawn cup was, in every case, much smaller than from that which was last drawn; and those between afforded less or more as they were nearer the beginning or the end. It is unnecessary here to specify these intermediate proportions; but it is proper the reader should be informed, that the quantity of cream obtained from the last-drawn cup, from some cows, exceeded that from the first in the proportion of sixteen to one. In other cows, however, and in particular circumstances, the disproportion was not quite so great; but in no case did it fall short of the rate of eight to one. Probably, upon an average of a great many cows, it might be found to run as ten or twelve to one.

Secondly, The difference in the quality of the cream, however, obtained from these two cups, was much greater than the difference in the quantity. In the first cup, the cream was a thin tough film, thinner, and perhaps whiter, than writing paper; in the last, the cream was of a thick *butyrous* consistence, and of a glowing richness of colour that no other kind of cream is ever found to possess.

Thirdly, The difference in the quality of the milk that remained, after the cream was separated, was perhaps still greater than either in respect to the quantity or the quality of the cream. The milk in the first cup was a thin bluish liquid, as if a very large proportion of water had been mixed with ordinary milk; that in the last cup was of a thick consistence, and yellow colour, more resembling cream than milk both in taste and appearance.

From this important experiment, it appears that the person who, by bad milking of his cows, loses but half a pint of his milk, loses in fact about as much cream as would be afforded by six or eight pints at the beginning, and loses, besides, that part of the cream which alone can give richness and high flavour to his butter.

"If milk be put into a dish, and allowed to stand till it throws up cream, that portion of cream which rises first to the surface is richer in quality, and greater in quantity, than what rises in a second equal space of time; and the cream that rises in the second interval of time is greater in quantity, and richer in quality, than that which rises in a third equal space of time; that of the third than the fourth, and so on: the cream that rises decreasing in quantity, and declining in quality, continually, as long as any rises to the surface."

Aphorism
2.

Our ingenious author confesses, that his experiments not having been made with so much accuracy in this case as in the former, he was not enabled to ascertain the difference in the proportion that takes place in equal portions of time; but they have been so often repeated as not to leave any room to doubt the fact, and it will be allowed to be a fact of no small importance in the management of the dairy. It is not certain, however, but that a greater quantity of cream may, upon the whole, be obtained from the milk by taking it away

(b) Cows should always be treated with great gentleness, and soothed by mild usage, especially when young and ticklish, or when the paps are tender; in which last case, the udder ought to be fomented with warm water before milking, and touched with the greatest gentleness, otherwise the cow will be in danger of contracting bad habits, becoming stubborn and unruly, and retaining her milk ever after. A cow never lets down her milk pleasantly to the person she dreads or dislikes. The udder and paps should always be washed with clean water before milking; but care should be taken that none of that water be admitted into the milking-pail.

Dairy. away at different times; but the process is so troublesome as not to be counterbalanced by the increased quantity obtained, if indeed an increased quantity be thus obtained, which is not as yet quite certain.

Aphorism 3. "Thick milk always throws up a smaller proportion of the cream it actually contains to the surface, than milk that is thinner; but that cream is of a richer quality. If water be added to that thick milk, it will afford a considerably greater quantity of cream than it would have done if allowed to remain pure, but its quality is, at the same time, greatly debased."

This is a fact that every person attentive to a dairy must have remarked; but I have never (says our author) heard of any experiment that could ascertain, either the precise amount of the increased quantity of cream that might thus be obtained, or of the ratio in the decrease of its quality. The effects of mixing water with the milk in a dairy are at least ascertained; and the knowledge of this fact will enable attentive persons to follow that practice which they think will best promote their own interest.

Aphorism 4. "Milk which is put into a bucket or other proper vessel, and carried in it to any considerable distance, so as to be much agitated, and in part cooled, before it be put into the milk-pans to settle for cream, never throws up so much, nor so rich cream, as if the same milk had been put into the milk-pans directly after it was milked."

In this case, it is believed the loss of cream will be nearly in proportion to the time that has elapsed, and the agitation the milk has sustained, after being drawn from the cow. But Dr Anderson says that he is not yet in possession of any experiments which sufficiently ascertain how much is to be ascribed to the time, and the agitation, taken separately. On every branch of agriculture we find experiments wanting, at each step we advance in our inquiries; and it is the duty of every enquirer to point out, as he goes along, where they are wanted, since the labours of no one man can possibly complete the whole.

From the above facts, the following corollaries seem to be clearly deducible:

First. It is of importance that the cows should be always milked as near the dairy as possible, to prevent the necessity of carrying and cooling the milk before it is put into the dishes; and as cows are much hurt by far driving, it must be a great advantage in a dairy-farm to have the principal grass fields as near the dairy or homestead as possible.

Secondly. The practice of putting the milk of all the cows of a large dairy into one vessel, as it is milked, there to remain till the whole milking is finished, before any part of it is put into the milk-pans—seems to be highly injudicious; not only on account of the loss that is sustained by agitation and cooling, but also, more especially, because it prevents the owner of the dairy from distinguishing the good from the bad cow's milk, so as to separate these from each other, where it is necessary. He may thus have the whole of his dairy product greatly debased by the milk of one bad cow, for years together, without being able to discover it. A better practice, therefore, would be, to have the milk drawn from each cow put separately into the creaming-pans as soon as it is milked, without being ever mixed with any other. Thus would the careful manager of

the dairy be able on all occasions to observe the particular quality of each individual cow's milk, as well as its quantity, and to know with precision which of his cows it was his interest to dispose of, and which of them he ought to keep and breed from.

Thirdly. If it be intended to make butter of a very fine quality, it will be advisable in all cases to keep the milk that is first drawn separate from that which comes last; as it is obvious, that if this be not done, the quality of the butter will be greatly debased, without much augmenting its quantity. It is also obvious, that if this is done, the quality of the butter will be improved in proportion to the smallness of the quantity of the last-drawn milk that is retained; so that those who wish to be singularly nice in this respect, will do well to retain only a very small portion of the last-drawn milk.

To those owners of dairies who have profit only in view, it must ever be a matter of trial and calculation, how far it is expedient for them to carry the improving of the quality of their butter at the expence of diminishing its quantity. In different situations prudence will point out different kinds of practice as most eligible; and all persons must be left, after making accurate trials, to determine for themselves. It is likewise a consideration of no small importance, to determine in what way the inferior milk, that is thus to be set apart where fine butter is wanted, can be employed with the greatest profit. In the Highlands of Scotland they have adopted, without thinking of the improvement of their butter, a very simple and economical practice in this respect. As the rearing of calves is there a principal object with the farmer, every cow is allowed to suckle her own calf with a part of her milk, the remainder only being employed in the dairy. To give the calf its portion regularly, it is separated from the cow, and kept in an inclosure, with all the other calves belonging to the same farm. At regular times, the cows are driven to the door of the inclosure, where the young calves fail not to meet them. Each calf is then separately let out, and runs directly to its mother, where it sucks till the dairy-maid judges it has had enough; she then orders it to be driven away, having previously shackled the hinder legs of the mother, by a very simple contrivance, to oblige her to stand still. Boys drive away the calf with switches, and return it to the inclosure, while the dairy-maid milks off what was left by the calf: thus they proceed till the whole of the cows are milked. They obtain only a small quantity of milk, it is true, but that milk is of an exceeding rich quality; which in the hands of such of the inhabitants as know how to manage it, is manufactured into the richest marrowy butter that can be anywhere met with. This richness of the Highland butter is universally ascribed to the old grass the cows feed upon in their remote glens; but it is in fact chiefly to be attributed to the practice here described, which has long prevailed in those regions. Whether a similar practice could be economically adopted elsewhere, our author takes not upon him to say; but doubtless other secondary uses might be found for the milk of inferior quality. On some occasions, it might be converted into butter of an inferior quality; on other occasions, it might be sold sweet, where the situation of the farm was within reach of a market-town; and on others, it might be converted into cheeses, which, by being made of sweet milk,

Dairy. would be of a very fine quality if carefully made (c). Still other uses might be devised for its application; of which the following is worthy of notice. Take common skimmed milk, when it has begun to turn sour, put it into an upright stand-churn, or a barrel with one of its ends out, or any other convenient vessel. Heat some water, and pour it into a tub that is large enough to contain with ease the vessel in which the milk was put. Set the vessel containing the milk into the hot water, and let it remain there for the space of one night. In the morning it will be found that the milk has separated into two parts; a thick cream-like substance, which occupies the upper part of the vessel, and a thin watery part that remains at the bottom. Draw off the thin part (called in Scotland *wigg*), by opening a stop-cock, placed for that purpose close above the bottom, and reserve the cream for use. Not much less than half of the milk is thus converted into a sort of cream, which, when well made, seems to be as rich and fat as real cream itself, and is only distinguishable from it by its founess. It is eaten with sugar, and esteemed a great delicacy, and usually sells at double the price of fresh unskimmed milk. It requires practice, however, to be able to make this nicely; the degree of the heat of the water, and many other circumstances, greatly affecting the operation.

Fourthly. If the quality of the butter be the chief object attended to, it will be necessary, not only to separate the first from the last drawn milk, but also to take nothing but the cream that is first separated from the best milk, as it is this first rising cream alone that is of the prime quality. The remainder of the milk, which will be still sweet, may be either employed for the purpose of making sweet milk cheeses, or may be allowed to stand, to throw up cream for making butter of an inferior quality, as circumstances may direct.

Fifthly. From the above facts, we are enabled to perceive, that butter of the very best possible quality can only be obtained from a dairy of considerable extent, judiciously managed; for when only a small por-

tion of each cow's milk can be set apart for throwing up cream, and when only a small proportion of that cream can be reserved, of the prime quality, it follows (the quantity of milk being upon the whole very inconsiderable), that the quantity of prime cream produced would be so small as to be scarcely worth manufacturing separately.

Sixthly. From these premises we are also led to draw another conclusion, extremely different from the opinion that is commonly entertained on this subject, viz. That it seems probable, that the very best butter could be made with economy in those dairies only where the manufacture of cheese is the principal object. The reasons are obvious: If only a small portion of milk should be set apart for butter, all the rest may be made into cheese, while it is yet warm from the cow, and perfectly sweet; and if only that portion of cream which rises during the first three or four hours after milking is to be reserved for butter, the rich milk which is left after that cream is separated, being still perfectly sweet, may be converted into cheese with as great advantage nearly as the newly-milked milk itself.

But as it is not probable that many persons could be found who would be willing to purchase the very finest butter, made in the manner above pointed out, at a price that would be sufficient to indemnify the farmer for his trouble in making it, these hints are thrown out merely to shew the curious in what way butter possessing this superior degree of excellence may be obtained, if they choose to be at the expence; but for an ordinary market, Dr Anderson is satisfied, from experience and attentive observation, that if in general about the first drawn half of the milk be separated at each milking, and the remainder only set up for producing cream, and if that milk be allowed to stand to throw up the whole of its cream (even till it begins sensibly to taste sourish), and that cream be afterwards carefully managed, the butter thus obtained will be of a quality greatly superior to what can usually be procured at market, and its quantity not considerably less than if the whole of

(c) The making of cheese has never yet been reduced to scientific principles, and consequently the reasoning relating to it is very inconclusive. It is in general supposed, that the goodness of cheese depends almost entirely upon its richness, by which is meant the proportion of oily matter, whether natural or extraneous, it contains; nothing, however, is more certain, than that this opinion is erroneous. Sometimes a very lean cheese is much better tasted than one that is much fatter; and, which will appear to most persons still more extraordinary, it frequently happens that a cheese that tastes soft and fat is much leaner than one that is hard, dry, and sticky. The mode of manufacturing it occasions this, and not the quantity of cream it contains. It is very possible by art to make poor skim milk cheese assume the soft buttery taste and appearance even of cream cheese. This subject, therefore, deserves to be more particularly elucidated than it has hitherto been.

Connected as they are with the object discussed in the text, we beg leave with our author to suggest the following particulars, as proper objects of examination and experiment, viz. Is the quantity of caseous matter afforded by milk necessarily connected with the proportion of cream that milk contains, or does it depend upon some other principle not hitherto investigated? Without pretending to decide this question, Dr Anderson feels himself strongly inclined to believe it does not depend upon the quantity of cream. It is well known that cow's milk, which always throws up more cream, and that of a much richer quality, than ewe-milk, does in no case afford above one-half the proportion of cheese that ewe-milk does. Nor can this singular tendency of ewe-milk, to yield a great proportion of curd, be attributed to its superior thickness; for cow-milk can be often had that is thicker and richer than ewe-milk, but it always affords a much smaller proportion of curd. From these considerations, it is not impossible but it might be found, upon a careful investigation, that the refuse milk, which ought to be separated from the other in making the best butter, might be equally proper, or very nearly so, for making cheese, as if no such separation had been made. We therefore recommend this as a proper object of experimental enquiry.

Dahalac. of the milk had been treated alike. This, therefore, is the practice that our author thinks most likely to suit the frugal farmer, as his butter, though of a superior quality, could be afforded at a price that would always ensure it a rapid sale.

Dr Anderson throws out many other ingenious and useful observations on this important branch of rural economy. In particular, he points out, in the plainest manner, the requisites of a good milk-house, which, as he truly observes, should be cool in summer and warm in winter, so as to preserve a temperature nearly the same throughout the year. But we have treated of this part of the subject elsewhere, and must therefore refer such as are desirous to know the Doctor's sentiments on it, to *The Letters and Papers of the Bath and West-of-England Society* for the encouragement of agriculture, &c. or to the eighth volume of *The Repository of Arts and Manufactures*.

DAHALAC, the largest island in the Red Sea, is thus described by Mr Bruce. It is low and even, the soil fixed gravel and white sand, mixed with shells and other marine productions. It is destitute of all sorts of herbage, at least in summer, unless a small quantity of bent grass, just sufficient to feed the few antelopes and goats that are on the island. There is a very beautiful species of this last animal found here, small, short-haired, with thin black sharp horns, having rings upon them, and they are very swift of foot.

This island is, in many places, covered with large plantations of acacia trees, which grow to no height, seldom above eight feet, but spread wide, and turn flat at top, probably by the influence of the wind from the sea. Though in the neighbourhood of Abyssinia, Dahalac does not partake of its seasons; no rain falls here from the end of March to the beginning of October; but in the intermediate months, especially December, January, and February, there are violent showers for 12 hours at a time, which deluge the island, and fill the cisterns so as to serve all next summer; for there are no hills nor mountains in Dahalac, and consequently no springs. These cisterns alone preserve the water, and of them there yet remain 370, all hewn out of the solid rock. They say these were the works of the Persians; it is more probable they were those of the first Ptolemies. But whoever were the constructors of these magnificent reservoirs, they were a very different people from those that now possess them, who have not industry enough to keep one of the 370 clear for the use of man. All of them are open to every sort of animal, and half full of the filth they leave there, after drinking and washing in them; yet one of these cisterns, cleaned and shut up with a door, might afford them wholesome sweet water all the year over.

After the rains fall, a prodigious quantity of grass immediately springs up; and the goats give the inhabitants milk, which in winter is the principal part of their subsistence, for they neither plow nor sow; all their employment is to work the vessels which trade to the different parts of the coast. One half of the inhabitants is constantly on the Arabian side, and by their labour is enabled to furnish with *dora* (millet or Indian corn) and other provisions the other half who stay at home; and when their time is expired, they are relieved by the other half, and supplied with necessaries in their turn. But the sustenance of the poorer sort is entirely

shell and other fish. Their wives and daughters are very bold and expert fisherwomen. Several of them, entirely naked, swam off to the vessel before it came to an anchor, begging handfuls of wheat, rice, or *dora*. They are very importunate and sturdy beggars, and not easily put off with denials. These miserable people, who live in the villages not frequented by barks from Arabia, are sometimes a whole year without tasting bread. Yet such is the attachment to their place of nativity, they prefer living in this bare, barren, parched spot, almost in want of necessaries of every kind, especially of these essential ones, bread and water, to those pleasant and plentiful countries on both sides of them.

There are in Dahalac twelve villages or towns, of which each has a plantation of doomtrees round it, which furnish the only manufacture in the island. The leaves of this tree, when dried, are of a glossy white, which might very easily be mistaken for fatten: of these they make baskets of surprising beauty and neatness, staining part of the leaves with red or black, and working them into figures very artificially. Our author knew some of these, resembling straw-baskets, continue full of water for 24 hours, without one drop coming through. They sell these at Loheia and Jidda, the largest of them for four commesh, or sixpence. This is the employment, or rather amusement, of the men who stay at home; for they work but very moderately at it, and all of them indeed take special care not to prejudice their health by any kind of fatigue from industry.

People of the better sort, such as the Shekh and his relations, men privileged to be idle, and never exposed to the sun, are of a brown complexion. But the common sort employed in fishing, and those who go constantly to sea, are not indeed black but red, and little darker than the colour of new mahogany.

The inhabitants of Dahalac seemed to be a simple, fearful, and inoffensive people. It is the only part of Africa or Arabia (call it which you please) where you see no one carry arms of any kind: neither gun, knife, nor sword, is to be seen in the hands of any one. Whereas at Loheia, and on all the coast of Arabia, and more particularly at Yamboo, every person goes armed; even the porters, naked and groaning under the weight of their burden and heat of the day, have yet a leather belt, in which they carry a crooked knife, so monstrously long, that it needs a particular motion and address in walking not to lame the bearer. This was not always the case at Dahalac; several of the Portuguese, on their first arrival here, were murdered, and the island often treated ill, in revenge, by the armaments of that nation. The men seemed healthy. They told our author they had no diseases among them, unless sometimes in spring, when the boats of Yemen and Jidda bring the small-pox among them, and very few escape with life that are infected. He did not observe among them a man that seemed to be sixty years old; from which he inferred that they are not long lived, though the air should be healthy, as being near the channel, and as they have the north wind all summer, which moderates the heat.

Dahalac, like all the other islands in the Red Sea, depends upon Masuah. The revenue of its governor consists in a goat brought to him monthly by each of the twelve villages. Every vessel that puts in there for Masuah pays him also a pound of coffee, and every one

Dahalac. from Arabia a dollar or pataka. No sort of small money is current at Dahalac, excepting Venetian glass-beads, old and new, of all sizes and colours, broken and whole.

Although this is the miserable state of Dahalac at present, matters were widely different in former times. The pearl fishery flourished greatly here under the Ptolemies; and even long after, in the time of the caliphs, it produced a great revenue, and till the sovereigns of Cairo, of the present miserable race of slaves, began to withdraw themselves from their dependency on the port, Dahalac was the principal island that furnished the pearl fishers or divers. It was, indeed, the chief port for the fishery on the southern part of the Red Sea, as Suakem was on the north; and the basha of Mafuah passed part of every summer here, to avoid the heat at his place of residence on the continent.

The fishery extended from Dahalac and its islands nearly to lat. 20°. The inhabited islands furnished each a bark and so many divers, and they were paid in wheat, flour, &c. such a portion to each bark for their use, and so much to leave with their family for their subsistence; so that a few months employment furnished them with every thing necessary for the rest of the year. The fishery was rented in later times to the basha of Suakem; but there was a place between Suakem and the supposed river Frat, in lat. 21° 28' north, called *Gungnab*, which was reserved to the grand signior in particular, and a special officer was appointed to receive the pearls on the spot and send them to Constantinople. The pearls found there were of the largest size, and inferior to none in water or roundness. Tradition says, that this was exclusively the property of the Pharaohs; by which is meant, in Arabian manuscripts, the old kings of Egypt before Mahomet.

In the same extent between Dahalac and Suakem was another very valuable fishery, that of tortoises, from which the finest shells of that kind were produced, and a great trade was carried on with the East Indies (China especially) at little expence, and with very considerable profits. But the immense treasures in the bottom of the Red Sea have now been abandoned for near 200 years, though they never were richer in all probability than at present. No nation can now turn them to any profit but the English East India Company, more intent on multiplying the number of their enemies, and weakening themselves by spreading their inconsiderable force over new conquests, than creating additional profit by engaging in new articles of commerce. A settlement upon the river Frat, which never yet has belonged to any one but wandering Arabs, would open them a market both for coarse and fine goods from the southern frontiers of Morocco, to Congo and Angola, and set the commerce of pearls and tortoise shell on foot again. All this section of the gulf from Suez, as we are told, is in their charter, and twenty ships might be employed on the Red Sea without any violation of territorial claims. The myrrh, the frankincense, some cinnamon, and variety of drugs, are all in the possession of the weak king of Adel; an usurper, tyrant, and Pagan, without protection, and willing to trade with any superior power that only would secure him a miserable livelihood.

There are neither horses, dogs, sheep, cows, nor any sort of quadruped but goats, asses, a few half-starved

camels, and antelopes at Dahalac, which last are very numerous. The inhabitants have no knowledge of fire-arms, and there are no dogs nor beasts of prey in the island to kill them; they catch indeed some few of them in traps.

The language at Dahalac is that of the shepherds, though Arabic, too, is spoken by most of them. Our author states the latitude of Dahalac to lie between 15° 27' 30", and 15° 54' 30" north.

DALRYMPLE (Sir David), was born in Edinburgh on the 28th of October (N. S.) 1726. His father was Sir James Dalrymple of Hailes, Bart. and his mother Lady Christian Hamilton, a daughter of the Earl of Hadinton. His grandfather Sir David Dalrymple was the youngest son of the first Lord Stair, and is said to have been the ablest of that family, so much distinguished for ability. He was Lord Advocate for Scotland in the reign of George I. and his son Sir James had the auditorship of the exchequer for life.

The subject of this memoir was educated at Eton school, where he was distinguished as a scholar, and long remembered as a virtuous and orderly youth. In that justly celebrated seminary he acquired a classical taste, which, though it was once prevalent in Scotland, has in that country been long on the decline; and formed, besides, friendships to persons and attachments to things, which accompanied him through life. Hence probably sprung his partiality to English manners and customs, which marked both his public conduct and private conversation, and was the source of much of his dignity, and some of his littlenesses.

From Eton he returned to Edinburgh, whence, after the usual course of a gentleman's studies in that university, he went to Utrecht to study the civil law; and remained there till after the rebellion in 1746. Upon his return to his native country, so promising were his parts, and such his industry and soberness of mind, that very sanguine expectations were entertained of his future eminence; and in some respects these expectations were not frustrated. To his intimate friends it was well known, that if left to follow the bent of his own inclinations, he would have devoted his time and his talents to the study of antiquities and the belles lettres; in both which departments of literature he was eminently qualified to excel. On the death of his father, however, he found his affairs so very much encumbered, that in order to retrieve them, and to provide for his brothers and sisters, he resolved to follow the law as a profession, in which some of his ancestors had made a distinguished figure.

He was called to the Scotch bar in 1748, where, notwithstanding the elegant propriety of the cases which he drew, it must be confessed that his success did not answer the expectations which had been formed of him. This was not owing either to want of science or to want of industry, but to certain peculiarities, which, if not inherent in his nature, were the result of early and deep-rooted habits. He possessed on all occasions a sovereign contempt, not only for verbal antithesis, but for the semblance of declamation; and indeed he was wholly unfitted by an ill toned voice and ungraceful elocution, for shining as an orator. No wonder, then, that his pleadings, which were never addressed to the passions,

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ple. passions, did not rival those of some of his opponents, who, possessed of great rhetorical powers, did not, like him, employ strokes of irony too fine to be perceived by the bulk of any audience, but expressed themselves in full, clear, and harmonious periods. Even his memorials, though classically written, and often replete with valuable matter, did not on every occasion please the court; for they were always brief, and sometimes, as it was said, indicated more attention to the minutæ of forms than to the merits of the cause. Yet on points which touched his own feelings, or the interests of truth and virtue, his language was animated, his arguments forcible, and his scrupulous regard to form thrown aside.

He was sometimes employed as a depute advocate, which gave him opportunities at the circuits of displaying that candour and tenderness of disposition which so well becomes the public prosecutor in a criminal court. Of this the following instance may be worth relating. On the first day of the court at Stirling, he was once accosted by another advocate in these words: "Sir David, why is there not a trial this forenoon? I would be getting on." "There are (replied he) some unhappy culprits to be tried for their *lives*; and therefore it is proper that they have time to confer with their men of law." "That is of little consequence (said the other). Last year I came to visit Lord Kames when he was here on the circuit, and he appointed me counsel for a man accused of a rape. Though I had very little time to prepare, yet I made a decent speech." "Pray, Sir, (said Sir David), was your client acquitted or condemned?" "O (replied the other), most unjustly condemned." "That, Sir, (said the depute advocate) is no good argument for hurrying on trials."

To return from this digression, if it be considered as such, it is surely to the honour of Sir David Dalrymple, that whatever men thought of his singularities, his detractors concurred with his admirers in believing him incapable of misleading the judge by a false statement of facts; or his clients, by holding out to them fallacious grounds of hope.

His high sense of honour, and his inflexible integrity, were indeed universally admitted; and it was with the warmest approbation of the public, that in 1766 he was appointed one of the judges of the court of session, the highest civil tribunal in Scotland. He took his seat on the bench, according to the usage of that court, by the title of Lord Hailes, the designation by which he is generally known among the learned of Europe; and the expectations entertained of him were again sanguine. His unwearied assiduity in sifting dark and intricate matters to the bottom was well known; his elegant and concise manner of expressing his sentiments was admirably suited to the character of a judge; and his legal opinions had been generally sound. Yet it must be confessed, that as a judge he was neither so useful nor so highly revered as he ought to have been from the extent of his knowledge, and his unquestioned integrity. The same minute attention to forms, which had in some degree obstructed his rise at the bar, ac-

companied him to the bench, and brought upon him the ridicule of the wits about the court (A): and we all know, that the character even of Socrates himself was not able to resist the torrent of ridicule. In extension of this foible, it may be observed, that by some of the judges of the court of session perhaps too little regard has been paid to form; and that forms, even apparently trifling, cannot in legal proceedings be wholly disregarded without involving in danger truth and justice. Be this as it may, such was the opinion which the other judges entertained of Lord Hailes's accuracy, diligence, and dignified manners, that, in the absence of the president, they generally voted him into the vacant chair.

In May 1776 he was appointed one of the lords commissioners of judicary; and in that station he commanded the respect of all mankind. Fully impressed with a deep sense of the importance of his office, he seemed, in the criminal court, to lay aside his singularities. So far from throwing his whole weight into the scale of the crown, a charge which has been sometimes brought, we believe unjustly, against the Scotch judges, Lord Hailes, like the judges of England, was always counsel for the prisoner when the king's counsel appeared too strong for their opponents, or when there was any particular intricacy in the case. In administering the oath to the witnesses, he had none of that indecorum which we have elsewhere censured in some of his brethren (see OATH, *Encycl.*); but rising solemnly from his seat, he repeated the words in so serious a manner, as left no doubt in the most profligate mind but that he was himself impressed with a sense of the immediate presence of the Supreme Being, and with the firm belief of a future judgment. When the witness appeared to be young or ignorant, we have beheld, with the utmost love and veneration, the pious pains which his Lordship took to discover whether he was duly acquainted with the nature and obligation of an oath, before he admitted him to swear; and though it is perhaps impossible for human vigilance and sagacity to prevent perjury altogether in courts of justice, he must surely have been a villain uncommonly hardened and artful who could perjure himself in the presence of Lord Hailes. In doubtful cases his Lordship inclined always to the side of mercy; but when it became his duty to pass sentence of death upon convicted criminals, he addressed them in a strain of such piety and commiseration, as to draw tears from the eyes of every beholder, and was calculated to make a deep and proper impression on the unhappy person himself. In the discharge of this painful duty, we never saw him surpassed, and have seldom seen him equalled.

Had Lord Hailes been conspicuous only as a sound lawyer and an able and upright judge, we should not have thought his life intitled to a place in this Work; but he was no less eminent as a man of general erudition, and as a voluminous author. His skill in classical learning, the belles lettres, and historical antiquities, especially those of his own country, is universally admitted;

(A) In a satirical ballad on the court of session, Mr Boswell, alluding to Lord Hailes's fondness for verbal criticism, makes him address the president in the following words:

To judge of this matter I cannot pretend,
For justice, my Lord, wants an *ε* at the end.

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ted; but it cannot be denied, that the same fastidiousness, and the same microscopic attention to minutiae, which characterised him as a barrister, prevented him from rising to that rank in the republic of letters to which his learning and genius would otherwise have infallibly carried him. But if he was not one of the most celebrated writers of the age, he was unquestionably one of the most virtuous; if his publications were not always edifying, they were at least innocent and ingenious; and some of them are in the highest degree valuable. In proof of this assertion, we need instance only his *Annals of Scotland*, and his *Inquiry into the Secondary Causes which Mr Gibbon has assigned for the Rapid Progress of Christianity*. Of the former of these works, though little calculated to please the common herd of readers, it may with truth be said, that in research and ingenuity it stands unrivalled among the writings of Scotch antiquaries; and of the latter, it is surely not too much to say, that it displays uncommon acumen, closeness of reasoning, and zeal for the cause of truth, without the usual rancour of theological controversy.

His taste for retirement, which the state of his affairs rendered for a while necessary, grew upon him as he advanced in years. His constitution, of which he was very careful, as well as his principles and habits, rendered him averse from dissipation of every kind. After he was made a judge, he considered abstraction from the gay and fashionable world as connected with the duty of one whose time was no longer his own; and when he chose to unbend his mind, it was in the society of a few easy friends, whom he selected as much for their worth and good humour as for their genius or their learning. He had indeed occasionally much conversation with that constellation of wits and men of science who flourished in Edinburgh at the same period with himself; but it was impossible for friendship or intimacy to subsist between men who thought so differently as he and they thought on the most important of all subjects. Though an old-fashioned whig, zealously attached to the constitution, he scorned to take any share in the civil or ecclesiastical broils in which some of his brother judges were warmly engaged for the first 20 years of the present reign; for he looked on these as either frivolous or mischievous.

Although his Lordship's constitution had been long in an enfeebled state, he prosecuted his studies, and attended his duty on the bench, till within three days of his death, which happened on the 29th of November 1792, in the 66th year of his age.

His Lordship was twice married; by his first wife Anne Brown, only daughter of Lord Coalston, one of the judges of the court of session, he left issue one daughter, who inherits the family estate. His second marriage (of which also there is issue one daughter) was to Helen Fergusson, youngest daughter of Lord Kilkerran, who has the affliction to survive him. Leaving no male issue, the title of Baronet descends to his nephew.

Though the church of Scotland does not much encourage funeral discourses, a very laudable endeavour was made to render the talents and virtues of Lord Hailes a theme of instruction to mankind, in a sermon preached soon after his death in the church of Inveresk, by his learned friend and venerable pastor Dr Carlyle;

from which we shall transcribe a summary view of his character as a judge, a scholar, a Christian, and a citizen.

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“ His knowledge of the laws was accurate and profound, and he applied it in judgment with the most scrupulous integrity. In his proceedings in the criminal court, the satisfaction he gave to the public could not be surpassed. His abhorrence of crimes, his tenderness for the criminals, his respect for the laws, and his reverential awe of the Omnipotent Judge, inspired him on some occasions with a commanding sublimity of thought, and a feeling solemnity of expression, that made condemnation seem just as the doom of Providence to the criminals themselves, and raised a salutary horror of crimes in the breast of the audience.

“ Conscious of the dignity and importance of the high office he held, he never departed from the decorum that becomes that reverend character; which indeed it cost him no effort to support, because he acted from principle and sentiment, both public and private. Affectionate to his family and relations, simple and mild in his manners, pure and conscientious in his morals, enlightened and entertaining in his conversation; he left society only to regret, that, devoted as he was to more important employments, he had so little time to spare for intercourse with them.

“ He was well known to be of high rank in the republic of letters, and his loss will be deeply felt through many of her departments. His labours, in illustration of the history of his country, and many other works of profound erudition, remain as monuments of his accurate and faithful research for materials, and his sound judgment in the selection of them. Of his unfeigned piety and devotion, you have very often been witnesses where we now are. I must add, however, that his attendance on religious ordinances was not merely out of respect to the laws and for the sake of example (motives which should never fail to have influence on persons of superior rank, for the most obvious reasons), but from principle and conviction, and the most conscientious regard to his duty; for he not only practised all the virtues and charities in proof of his faith, but he demonstrated the sincerity of his zeal by the uncommon pains he took to illustrate primitive Christianity, and by his elaborate and able defences of it against its enemies.

“ His profound researches into history, and his thorough knowledge of the laws, made him perfectly acquainted with the progress of the constitution of Britain, from the first dawn of liberty in the common law of the land, and the trial by jury which precede all written records, and afterwards in the origin and establishment of parliaments, through all its vicissitudes and dangers, till at last, by the blessing of divine Providence, which brought many wonderful events to concur to the same end, it was renewed, strengthened, and finally confirmed by the Revolution.

“ It was this goodly and venerable fabric of the British constitution which the deceased most respectable character contemplated with admiration and delight (of late, indeed, with a mixture of anxiety and fear), as the temple of piety, as the genuine source of greater happiness and freedom, to a larger portion of mankind than ever flowed from any government upon earth.

“ Ill indeed can the times bear the loss of such an affectionate

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ple. affectionate patriot and able guardian of the laws of his country. But we must not murmur at the will of Providence, which in its mercy 'may have withdrawn the good man from the evil to come.' In mercy, I say, to him, whose righteous spirit was so deeply grieved when 'he saw the wicked rage, and the people imagine a vain thing.'

Such is the memorial which, in the hour of recent sorrow, followed this excellent man to the grave; and we believe it will yet be allowed to be just by all who had the happiness of his Lordship's acquaintance, and are what he was, friends to the best interests of mankind.

This sketch of the life of Lord Hailes would be more imperfect than even it is, if we could not subjoin to it a catalogue of his publications, of which the greater part are exceedingly curious. We call them *publications*, because he employed almost as much of his time in republishing old and useful books as in preparing for the press his own valuable works.

Besides his essays in the papers called *The World* and *The Mirror*, which are well known and universally admired, his Lordship published the following works:

Sacred Poems, or a Collection of Translations and Paraphrases from the Holy Scriptures; by various authors, Edinburgh, 1751, 12mo. Dedicated to Charles Lord Hope, with a preface of ten pages.

The Wisdom of Solomon, Wisdom of Jesus the Son of Sirach, or Ecclesiasticus, 12mo, Edin. 1755.

Select Discourses (in number nine), by John Smith, late Fellow of Queen's College, Cambridge, 12mo, 291 pages. Edin. 1756; with a preface of five pages, "many quotations from the learned languages translated,—and notes added, containing allusions to ancient mythology, and to the erroneous philosophy which prevailed in the days of the author,—various inaccuracies of style have been corrected, and harsh expressions softened."

A discourse of the unnatural and vile Conspiracy attempted by John Earl of Gowry and his brother, against his Majesty's person, at St Johnstoun, upon the 5th of Aug. 1600. No date of the republication, but the edition and notes supposed by Lord Hailes, 12mo, 1757.

A Sermon, which might have been preached in East Lothian upon the 25th day of October 1761, on Acts xxviii. 1, 2. "The barbarous people shewed us no little kindness." Edin. 1761, pp. 25, 12mo. "Occasioned by the country people pillaging the wreck of two vessels, viz. the *Betsy*, Cunningham, and the *Leith Packet*, Pitcairn, from London to Leith, cast away on the shore between Dunbar and North Berwick. All the passengers on board the former, in number 17, perished; five on board the latter, October 16. 1761."—A most affecting discourse, admirably calculated to convince the offenders!

Memorials and Letters relating to the History of Britain, in the reign of James I. published from the originals, Glasgow, 1762.—Addressed to Philip Yorke, Viscount Royston, pp. 151. "From a collection in the advocate's library, by Balfour of Denmyln." The preface of four pages, signed Dav. Dalrymple.

The works of the ever memorable Mr John Hales of Eaton, now first collected together in 3 vols, Glasgow, 1765; preface of three pages. Dedicated to William (Warburton), Bishop of Gloucester. "The

edition said to be undertaken with his approbation; obsolete words altered, with corrections in spelling and punctuation." Dalrym-
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A specimen of a book entitled "Ane Compendious Booke of Godly and Spiritual Songs, collectit out of sundrie parts of the Scripture, with sundrie of other Ballates changed out of prophaine Sanges, for avoyding of Sin and Harlotrie, with augmentation of sundry Gude and Godly Ballates, not contained in the first edition. Edinburgh, printed by Andro Hart." 12mo. Edin. 1765, pp. 42; with a Glossary of four pages.

Memorials and Letters relating to the History of Britain in the reign of Charles I. published from the originals, Glasgow, 1766, pp. 189. Preface of six pages, signed Dav. Dalrymple, chiefly collected by Mr Wodrow, author of the History of the Church of Scotland. Inscribed to Robert Dundas of Arncliffe, Lord President of the Court of Session.

An account of the preservation of Charles II. after the Battle of Worcester, drawn up by himself; to which are added, his Letters to several persons. Glasgow, 1766, pp. 190, from the MSS. of Mr Pepys, dictated to him by the king himself, and communicated by Dr Sandby, master of Magdalen College. The letters are collected from various books; some of them now first published, communicated by the tutors of the Duke of Hamilton, by the Earl of Dundonald, &c. The preface of four pages, signed Dav. Dalrymple, dedicated to Thomas Holles, Duke of Newcastle, chancellor of the university of Cambridge.

The Secret Correspondence between Sir Robert Cecil and James VI. 12mo, 1766.

A catalogue of the Lords of Session, from the Institution of the College of Justice in the year 1532, with Historical Notes. *Suum cuique—rependet posteritas.* Edin. 1767, 4to, pp. 26.

The Private Correspondence of Dr Francis Atterbury, Bishop of Rochester, and his friends, in 1725, never before published. Printed in 1768, 4to. Advertisement, pp. 2. Letters, pp. 10. A fac simile of the first from Bishop Atterbury to John Cameron of Lochiel, to prove their authenticity.

An examination of some of the Arguments for the High Antiquity of *Regiam Majestatem*; and an Inquiry into the authenticity of the *Leges Malcolni*; by Sir David Dalrymple, 4to, pp. 52. Edin. 1769.

Historical Memoirs concerning the Provincial Councils of the Scottish Clergy, from the earliest Accounts to the Æra of the Reformation; by Sir David Dalrymple. Edinburgh, 1769, 4to, pp. 41.—*Nota*, Having no high opinion of the popularity of his writings, he prefixes to this work the following motto: "Si delectamur quum scribimus quis est tam invidus qui ab eo nos abducatur? sin laboramus quis est qui alienæ modum statuat industriæ."—*Cicero*.

Canons of the church of Scotland, drawn up in the Provincial Councils held at Perth, A. D. 1242, and 1269. Edinburgh, 1769, 4to, pp. 48.

Ancient Scottish Poems, published from the MS. of George Bannatyne, 1568. Edin. 1770, 12mo. Preface six pages; Poems pp. 221; very curious notes pp. 92; glossary and lists of passages and words not understood, pp. 14.

The additional case of Elizabeth, claiming the title and dignity of Countess of Sutherland; by her Guardians.

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dians. Wherein the facts and arguments in support of her claim are more fully stated, and the errors in the additional cases for the other claimants are detected, 4to.—This singularly learned and able case was subscribed by Alexander Wedderburn (present Lord Chancellor), and Sir Adam Ferguson, but is the well-known work of Lord Hailes. It ought not to be regarded merely as a law-paper of great ability, but as a treatise of profound research into the history and antiquity of many important and general points of succession and family history. Introduction, pp. 21; the first four chapters pp. 70; the fifth and sixth chapters pp. 177.

Remarks on the History of Scotland, by Sir David Dalrymple.—“*Utinam tam facile vera invenire possem quam falsa convincere.*” *Cicero*.—Edin. 1773, inscribed to George Lord Lyttleton, in nine chapters, pp. 284. 12mo.

Huberti Langueti Epistolæ ad Philippum Sydneium Equitem Anglum, accurante D. Dalrymple de Hailes, Esq. Edinburgh, 1776, 8vo. Inscribed to Lord Chief Baron Smythe.—*Virorum Eruditorum Testimonia de Langueto*, pp. 7. Epistolæ, pp. 289. Index Nominum, pp. 41.

Annals of Scotland, from the Accession of Malcolm III. surnamed Canmore, to the Accession of Robert I. by Sir David Dalrymple. Edin. 1776, pp. 311. Appendix, pp. 51.

Tables of the Succession of the Kings of Scotland, from Malcolm III. to Robert I. their marriages, children, and time of their death; and also of the Kings of England and France, and of the Popes who were their contemporaries.

Chronological Abridgement of the Volume, pp. 30. The Appendix contains eight dissertations: 1. Of the law of *Evenus* and *Mercheta Mulierum*, pp. 17. 2. A commentary on the 22d statute of William the Lion, pp. 8. 3. Of the 18th statute of Alexander III. pp. 5. 4. Bull of Pope Innocent IV. pp. 6. 5. Of Walter Stewart Earl of Menteith, 1296, pp. 7. 6. Of M'Duff, slain at Falkirk in 1298, pp. 3. 7. Of the death of John Comyn, 10th February, 1305, pp. 4. 8. Of the origin of the house of Stuart, pp. 6.

Annals of Scotland, from the Accession of Robert I. surnamed Bruce, to the Accession of the House of Stuart; by Sir David Dalrymple, Edin. 1779, 4to, pp. 277. Appendix, pp. 54, containing, 1. Of the manner of the death of Marjory, daughter of Robert I. pp. 7. 2. Journal of the campaign of Edward III. 1327, pp. 9. 3. Of the genealogy of the family of Seton in the 14th century. 4. List of the Scottish commanders at the battle of Halidon, 19th July 1383, pp. 11. 5. Whether Edward III. put to death the son of Sir Alexander Seton, pp. 8. 6. List of the Scottish commanders killed or made prisoners at the battle of Durham, pp. 8. 7. Table of kings, p. 1. 8. Corrections and additions to volume i. pp. 16. Chronological abridgement of the volume, pp. 39.

Account of the Martyrs of Smyrna and Lyons, in the 2d century, 12mo, with explanatory notes, Edin. 1776. Dedicated to Bishop Hurd, pp. 68. Notes and illustrations, pp. 142. This is a new and correct version of two most ancient epistles, the one from the church at Smyrna to the church at Philadelphia; the other from the Christians at Vienna and Lyons to those in Asia and Phrygia—their antiquity and authenticity are

undoubted. Great part of both is extracted from Eusebius's Ecclesiastical History. The former was first completely edited by Archbishop Usher. The author of the notes says of them, with his usual and singular modesty, “That they will afford little new or interesting to men of erudition, though they may prove of some benefit to the unlearned reader.” But the erudition he possessed in these branches is so rare, that this notice is unnecessary. They display much useful learning and ingenious criticism, and breathe the most ardent zeal, connected with an exemplary knowledge of Christianity. N. B. This is the first volume of the remains of Christian Antiquity.

Remains of Christian Antiquity, with explanatory notes, vol. ii. Edin. 1778, 12mo. Dedicated to Dr Newton bishop of Bristol. Preface, pp. 7. This volume contains the trial of Justin Martyr and his companions, pp. 8. Epistle of Dionysius bishop of Alexandria, to Fabius bishop of Antioch, pp. 16. The trial and execution of Cyprian bishop of Carthage, pp. 8. The trial and execution of Fructuosus bishop of Tarragona in Spain, and of his two deacons, Augurius and Eulogius, pp. 8. The maiden of Antioch, pp. 2. These are all newly translated by Lord Hailes from Ruinart, Eusebius, Ambrose, &c. The notes and illustrations of this volume extend from p. 47 to 165, and display a most intimate acquaintance with antiquity, great critical acumen, both in elucidating the sense and detecting interpolations; and above all, a fervent and enlightened zeal, in vindicating such sentiments and conduct as are conformable to the word of God, against the malicious sarcasms of Mr Gibbon. To this volume is added an Appendix of pp. 22, correcting and vindicating certain parts of vol. i.

Remains of Christian Antiquity, vol. iii. Edin. 1780. Dedicated to Thomas Balguy, D. D. Preface, pp. 2. It contains the History of the martyrs of Palestine in the third century, translated from Eusebius, pp. 94. Notes and illustrations, pp. 135; in which Mr Gibbon again comes, and more frequently, under review.—The partiality and misrepresentations of this popular writer are here exposed in the calmest and most satisfactory manner.

Pity it is that Lord Hailes should have printed and published these valuable volumes, and indeed most of his other works, at his own expence; and dispersed them so liberally to his friends, that they have been little circulated among any other.

Octavius, a Dialogue, by Marcus Minucius Felix. Edin. 1781, pp. 16. Preface.—The speakers are, Cæcilius a Heathen, Octavius a Christian; whose arguments prevail with his friend to renounce Paganism and become a Christian proselyte. Notes and illustrations, pp. 120.

Of the Manner in which the Persecutors died; a Treatise, by L. C. F. Lactantius, Edin. 1782. Inscribed to Dr Porteus bishop of Chester (present bishop of London). Preface, pp. 37, in which it is proved that Lactantius is the author. Text, pp. 125. Notes and illustrations, pp. 109.

L. C. F. Lactantii Divinarum Institutionum Liber Quintus sen de Justitia, 1777.

Disquisitions concerning the Antiquity of the Christian Church. Glasgow, 1783. Inscribed to Dr Halifax bishop of Gloucester, pp. 194.—This small original

Dalrym-
ple.

nal and most excellent work consists of six chapters. Chap. 1. A commentary on the conduct and character of Gallio. Acts xviii. 5, 12, 17.—Chap. 2. Of the time at which the Christian religion became publicly known at Rome.—Chap. 3. Cause of the persecution of the Christians under Nero. In this the hypothesis of Mr Gibbon, vol. i. 4to, p. 641, is examined.—Chap. 4. Of the eminent Heathen writers who are said (by Gibbon) to have disregarded or contemned Christianity, viz. Seneca, Pliny sen. Tacitus, Pliny jun. Galen, Epictetus, Plutarch, Marcus Antoninus. To the admirers of Heathen philosophers, and to those especially who state between them and the Christian doctrine any consanguinity, this chapter is earnestly recommended.—Chap. 5. Illustration of a conjecture by Gibbon, respecting the silence of Dio Cassius concerning the Christians. In this chapter, with extreme impartiality, he amplifies and supports an idea of Mr Gibbon on this head. Chap. 6. Of the circumstances respecting Christianity that are to be found in the Augustan history.

It seems very probable that the close attention which Lord Hailes appears to have given to such subjects, was in some measure the effect of the mistakes and partiality of Gibbon. In no one work from 1776, the date of Mr Gibbon's first publication, has he omitted to trace this unfair and insinuating author; but in 1786 he came forth of set purpose with the most able and formidable reply which he has received, intitled, "An Inquiry into the Secondary Causes which Mr Gibbon has assigned for the rapid growth of Christianity; by Sir David Dalrymple." Edin. 1786; gratefully and affectionately inscribed to Richard (Hurd) Bishop of Worcester, 4to, pp. 213. In five chapters.

Sketch of the Life of John Barclay, 4to, 1786.

Sketch of the Life of John Hamilton, a Secular Priest, 4to (one of the most savage and bigotted adherents of Popery, who lived about A. D. 1600.)

Sketch of the Life of Sir James Ramsay, a general officer in the armies of Gustavus Adolphus king of Sweden, with a head.

Life of George Leslie (an eminent capuchin friar in the early part of the 17th century, 4to, pp. 24.

Sketch of the Life of Mark Alex. Boyd, 4to.

These lives were written and published as a specimen of the manner in which a *Biographia Scotica* might be executed; and it is likely that Lord Hailes selected purposely the least interesting.

The Opinions of Sarah Dutchess Dowager of Marlborough, published from her original MSS. 1788, 12mo, pp. 120. (with a few foot notes by Lord Hailes, in which he corrects the splenetic partiality of her Grace).

The Address of Q. Sept. Tertullian to Scapula Tertullus, Proconsul of Africa, translated by Sir David Dalrymple, 12mo. Edin. 1790, inscribed to Dr John Butler, bishop of Hereford; preface, pp. 4; translation, pp. 18; original, pp. 13; notes and illustrations, pp. 135.

This address contains many particulars relating to the church after the third century. The translator has

rejected all words and phrases of French origin, and written entirely in the Anglo Saxon dialect. In the course of the notes many obscurities of the original, not adverted to by other commentators, are explained. Some strange inaccuracies of Mr Gibbon are also detected, not included in the misrepresentations of his two famous chapters.

This was the last work of this truly learned, respectable, and useful man. Whether he left behind him any thing else finished for the press, is known only to his friends. We have repeatedly heard that he was engaged in examining the authenticity of the books of the New Testament, and that, with the exception of two or three, he found every verse contained in it in the writings of the first three centuries. This seems indeed to have been an object in all his works; for, at the end of each of his translations and editions of the primitive Christian writers, a table is given of passages quoted or mentioned by them. If his Lordship completed any work of this kind, it should not be withheld from the public. We may indeed be told that its utility is in a great measure superseded by the laborious collections of Lardner (B), and the more elegant work of Paley (C); but not to mention the prejudices generally entertained against Lardner on account of his evident bias to Unitarianism, it would surely be proper, in the present age of wild opinions, to shew the multitude, who are guided by authority, how important a subject the Christian religion was deemed by this learned and accomplished layman.

DARCY (Count), an ingenious philosopher and mathematician, was born in Ireland in the year 1725; but his friends being, like many other great and good families at that period, attached to the house of Stuart, he was at 14 years of age sent to France, where he spent the rest of his life. Giving early indications of a genius for science, he was put under the care of the celebrated Clairaut (see CLAIRAUT, *Encycl*), under whose tuition he improved so rapidly in the mathematics, that at 17 years of age he gave a new solution of the problem concerning the curve of equal pressure in a resisting medium. This was followed the year after by a determination of the curve described by a heavy body, sliding by its own weight along a moveable plane, at the same time that the pressure of the body causes a horizontal motion in the plane.

Though Darcy served in the war of 1744, he found leisure, during the bustle of a military life, to send two memoirs to the academy: the first of these contained a general principle in mechanics, that of the preservation of the rotatory motion; a principle which he again brought forward in 1750, by the name of the principle of the preservation of action. He was taken prisoner in this war by the English; and such was either the respect paid to science, or the mercy of the cabinet of St James's, that he was treated, not as an Irish rebel, but as a French subject fighting for his king and his country.

In 1760, Darcy published An Essay on Artillery, containing some curious experiments on the charges of gunpowder, &c. &c. and improvements on those of the ingenious

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(B) See his *Credibility of the Gospel History*, and other works, in 11 vols 8vo.
(C) See his *Evidences of the Christian Religion*, in 2 vols 8vo.

Darcy,
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ingenious Robins; a kind of experiments which our author carried on occasionally to the end of his life. In 1765, he gave to the public the most ingenious of all his works, his Memoir on the Duration of the Sensation of Sight; in which he endeavours to prove, and indeed completely proves, that a body may sometimes pass by our eyes without producing a sensation attended with consciousness or marking its presence, otherwise than by weakening the brightness of the object which it may chance to cover in its passage. If in this work he shall be thought to have taken hints from Dr Hartley, it is not perhaps too much to say, that some of our most celebrated writers on vision have since been beholden to Darcy. No man indeed has cause to be ashamed of being indebted to him; for all his works display in an eminent degree the union of genius and philosophy; but as he measured every thing upon the largest scale, and required extreme accuracy in experiment, neither his time, fortune, nor avocations, allowed him to execute more than a very small part of what he projected.

In his disposition, Darcy was amiable, spirited, lively, and a lover of independence; a passion to which he nobly sacrificed, even in the midst of literary society.— He died of a cholera morbus in 1779, at 54 years of age. He was admitted of the French academy in 1749, and was made pensioner-geometrician in 1770. His essays, printed in the Memoirs of the Academy of Sciences, are various and very ingenious, and are contained in the volumes for the years 1742, 1747, 1749, 1750, 1751, 1752, 1753, 1754, 1758, 1759, 1760, 1765; and in tom. I. of the Savans Etrangers.

DATA OF EUCLID, the first in order of the books that have been written by the ancient geometricians, to facilitate and promote the method of resolution or analysis. In general, a thing is said to be given which is either actually exhibited or can be found out, that is, which is either known by hypothesis, or that can be demonstrated to be known: and the propositions in the book of Euclid's data shew what things can be found out or known, from those that by hypothesis are already known: so that in the analysis or investigation of a problem, from the things that are laid down as given or known, by the help of these propositions, it is demonstrated that other things are given, and from these last that others again are given, and so on, till it is demonstrated that that which was proposed to be found out in the problem is given; and when this is done, the problem is solved, and its composition is made and derived from the compositions of the data which were employed in the analysis. And thus the data of Euclid are of the most general and necessary use in the solution of problems of every kind.

Marinus, at the end of his preface to the data, is mistaken in asserting that Euclid has not used the synthetical, but the analytical method in delivering them: for though in the analysis of a theorem, the thing to be demonstrated is assumed in the analysis; yet in the demonstrations of the data, the thing to be demonstrated, which is, that something is given, is never once assumed in the demonstration; from which it is manifest, that every one of them is demonstrated synthetically: though indeed if a proposition of the data be turned into a problem, the demonstration of the proposition be-

comes the analysis of the problem. *Simpson's Preface to his Edition of the Data.*

CIRCULATING DECIMALS, called also *recurring* or *repeating decimals*, are those in which a figure or several figures are continually repeated. They are distinguished into *single* and *multiple*, and these again into *pure* and *mixed*.

A *pure single* circulate is that in which one figure only is repeated; as $\cdot 222$, &c. and is marked thus $\cdot 2$.

A *pure multiple* circulate is that in which several figures are continually repeated; as $\cdot 232323$, &c. marked $\cdot 23$; and $\cdot 524524$, &c. marked $\cdot 524$.

A *mixed single* circulate is that which consists of a terminate part, and a single repeating figure; as $4\cdot 222$, &c. or $4\cdot 2$. And

A *mixed multiple* circulate is that which contains a terminate part with several repeating figures; as $45\cdot 524$.

That part of the circulate which repeats is called the *repetend*; and the whole repetend, supposed infinitely continued, is equal to a vulgar fraction, whose numerator is the repeating number or figures, and its denominator the same number of nines: so $\cdot 2$ is $= \frac{2}{9}$; and $\cdot 23$ is $= \frac{23}{99}$; and $\cdot 524$ is $= \frac{524}{999}$.

It seems it was Dr Wallis who first distinctly considered or treated of infinite circulating decimals, as he himself informs us in his Treatise of infinites. Since his time many other authors have treated on this part of arithmetic; the principal of these, however, to whom the art is mostly indebted, are Messrs Brown, Cunn, Martin, Emerson, Malcolm, Donn, and Henry Clarke; in whose writings the nature and practice of this art may be fully seen, especially in the last mentioned ingenious author.

DEFERENS, or DEFERENT, in the ancient astronomy, an imaginary circle, which, as it were, carries about the body of a planet, and is the same with the eccentric; being invented to account for the eccentricity, perigee, and apogee of the planets.

DEFLECTION, the turning any thing aside from its former course by some adventitious or external cause. The word is often applied to the tendency of a ship from her true course by reason of currents, &c. which turn her out of her right way. It is likewise applied by astronomers to the tendency of the planets from the line of their projection, or the tangent of their orbit. See ASTRONOMY in this Supplement.

DEJECTION, in astrology, is applied to the planets when in their detriment, as astrologers speak, i. e. when they have lost their force or influence, as is pretended, by reason of their being in opposition to some others which check and counteract them. Or it is used when a planet is in a sign opposite to that in which it has its greatest effect or influence, which is called its *exaltation*. Thus, the sign Aries being the exaltation of the sun, the opposite sign Libra is its dejection.

DELIACAL PROBLEM, a celebrated problem among the ancients, concerning the duplication of the cube.

DEMI-BASTION, in fortification, a bastion that has only one face and one flank.

DENDROMETER, in its usual acceptance, is the name of an instrument for measuring trees, of which the reader will find a description in the Encyclopædia Britannica. The same name has been lately given, by

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WILLIAM PITT, Esq; of Pendeford near Wolverhampton, to an instrument proposed by him for measuring distances by one observation.

The idea of such an instrument is not new. It has been frequently discussed, both in conversation and upon paper; but has been generally treated by sound mathematicians with contempt, on the supposition of its being founded on false principles. Of all this our author is fully aware; but he, notwithstanding, strongly recommends it to the attention of the ingenious mathematical instrument maker.

To determine distances by one observation, two methods may be proposed, founded on different principles; the one on the supposition of the observer being in the centre, and the object in the circumference, of a circle; the other, on the contrary supposition, of the observer being in the circumference, and the object in the centre.

To determine the distance of any object on the first supposition, the bulk or dimensions of such object must be known, either by measure or estimation, and the angle formed by lines drawn to its extremities being taken by an accurate instrument, the distance is easily calculated; and such calculations may be facilitated by tables or theorems adapted to that purpose. For this method our present instruments, with a nonius, and the whole very accurately divided, are sufficient; the only improvement wanting seems to be the application of a micrometer to such instruments, to enable the observer to read his angle with more minute accuracy, by ascertaining, not only the degrees and parts of a degree, but also the minutes and parts of a minute.

As in this method the bulk of inaccessible objects can only be estimated, the error in distance will be exactly in the proportion of the error in such estimation; little dependence can therefore be placed on distances thus ascertained. For the purposes of surveying, indeed, a staff of known length may be held by an assistant; and the angle from the eye of the observer to its two ends being measured by an accurate instrument, with a micrometer fitted to ascertain minutes and parts of a minute, distances may be thus determined with great accuracy; the application of a micrometer to the theodolite, if it could be depended upon, for thus determining the minute parts of a degree, in small angles, is very much a desideratum with the practical surveyor.

This method of measuring distances, though plain and simple enough, our author illustrates by an example: Suppose A, fig. 1. (see Plate XXI.) the place of the instrument; BC the assistant's staff, with a perpendicular pin at D, to enable the assistant to hold it in its right position; now, if the angle BAC could, by the help of a micrometer, be ascertained to parts of a minute, the distance from A to B, or to C, might be easily calculated by the rules of plane TRIGONOMETRY; for which see that article in the Encyclopædia.

But this method of ascertaining distances cannot be applied to inaccessible objects, and it is moreover subject to the inconvenience of an assistant being obliged to go to the object whose distance is required (an inconvenience almost equal to the trouble of actual admeasurement); therefore the perfection of the second method proposed, if attainable, is principally to be desired; namely, that of conceiving the observation made on the circumference of a circle, whose centre is in the

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object whose distance is to be ascertained; and, none of our instruments now in use being adapted to this mode of observation, a new construction of a mathematical instrument is therefore proposed, the name intended for which is the *dendrometer*.

Our author admits, that this name is not now used for the first time, though he thinks that the principle has never been applied in practice, for the familiar purpose of ascertaining terrestrial distances, in surveying, or otherwise, though the same principle has been so generally and successfully applied in determining the distance of the heavenly bodies by means of their parallax.

The following principles of construction are proposed, which may perhaps be otherwise varied and improved. O, fig. 2. the object of whose distance is required; ABCDE the instrument *in plano*; BC a telescope, placed exactly parallel to the side AE; CE an arch of a circle, whose centre is at A, accurately divided from E in degrees, &c.; AD an index, moveable on the centre A, with a nonius scale at the end D, graduated to apply to the divisions of the arch; also with a telescope, to enable the observer to discriminate the object, or any particular part or side thereof, the more accurately. The whole should be mounted on three legs, in the manner of a plain table or theodolite, and furnished with spirit-tubes to adjust it to an horizontal position. The instrument being placed in such position, the telescope BC must be brought upon the object O, or rather upon some particular point or side thereof; when, being there fastened, the index AD must be moved till its telescope exactly strikes the same point of the object; then the divisions on the arch ED mark out the angle DAE, which will be exactly equal to the angle BOA, as is demonstrated in the XV. and XXIX. propositions of Euclid, Book I.; and the side BA, as well as the angles ABO, and BAO, being already known, the distance BO or AO may be easily determined.

As the perfection of this instrument depends altogether upon its accuracy in taking small angles, so that accuracy must depend, not only upon the instrument's being properly fitted with a micrometer, but also in some measure upon the length of the line BA in the figure. That line, therefore, might be extended, by the instrument being constructed to fold or slide out to a greater length when in use; upon which principle, connected with the application of a micrometer, an accurate and useful instrument might certainly be constructed. To adjust such instrument for use, let a staff be held up at a distance, in the manner of fig. 1. exactly equal in length to the distance of the two telescopes, and the index AD being brought exactly upon the side AE, if the two telescopes accurately strike either end of the staff, the instrument is properly adjusted.

The construction of a similar instrument, on the principles of Hadley's quadrant, for naval observations, would also doubtless be an acceptable object in navigation, by enabling the mariner to ascertain the distances of ships, capes, and other objects, at a single observation; and that, perhaps, with greater accuracy than can be done by any method now in use.

For this purpose, the following construction is proposed: ABCDE, fig. 3. the instrument *in plano*; O the object whose distance is required; at A, at C, at E, and at 3, are to be fixed speculums, properly framed

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med and fitted, that at 3 having only its lower part quicksilvered, the upper part being left transparent to view the object; the speculum at A being fixed obliquely, so that a line A 1, drawn perpendicular to its surface, may bisect the angle BAC in equal parts; that at C being perpendicular to the line C 2; those at E and 3 being perpendicular to the index E 3, and that at E being furnished with a sight; the arch DC to be divided from D in the manner of Hadley's quadrant; the movement of the index to be measured as before by a micrometer; and as the length of the line AE would tend to the perfection of the instrument, it may be constructed to fold up in the middle, on the line C 2, into less compass when not in use. The instrument may be adjusted for use by holding up a staff at a distance, as before proposed, whose length is exactly equal to the line AE.

To make an observation by this instrument, it being previously properly adjusted, the eye is to be applied at the sight in the speculum E, and the face turned towards the object; when the object being received on the speculum A, is reflected into that at C, and again into that at E, and that at 3 on the index; the index being then moved till the reflected object in the speculum at 3 exactly coincides with the real object in the transparent part of the glass, the divisions on the arch D 3, subdivided by the micrometer, will determine the angle DE 3 = the angle AOE; from which the distance O may be determined as before.

DENOMINATOR OF A RATIO is the quotient arising from the division of the antecedent by the consequent. Thus, 6 is the denominator of the ratio 30 to 5, because 30 divided by 5 gives 6. It is otherwise called the *exponent* of the ratio.

DEPRESSION OF A STAR, or of the Sun, is its distance below the horizon; and is measured by an arc of a vertical circle, intercepted between the horizon and the place of the star.

DEPRESSION of the Visible Horizon, or Dip of the Horizon, denotes its sinking or dipping below the true horizontal plane, by the observer's eye being raised above the surface of the sea; in consequence of which, the observed altitude of an object is by so much too great.

DEROBBUST, in Bengal, Entire; as an entire district, opposed to KISMUR, which see.

DESAULT (Peter Joseph), surgeon in chief to the Hospital of Humanity, formerly the *Hotel-Dieu* at Paris, was born on the 6th of February 1744 at Magny Vernois, a village in the neighbourhood of Lure, in the department of Haute Saone (formerly the province of *Franche Comté*). His father and mother were in that situation of life which is removed from want, and yet does not dispense with labour; he himself was the youngest child of a numerous family.

At Lure, under the direction of a private instructor, he was taught the first rudiments of the Latin tongue; his parents afterwards confided him to the care of the Jesuits, then almost exclusively entrusted with the education of youth in the public schools. This celebrated society, prompt in discovering, as expert at developing, and adroit in appropriating talents, soon distinguished the young student from the crowd; and he, in his turn, was not displeased with the life he led in one of their seminaries.

Default.

On the completion of his studies, his father, who had destined him for the church, intimated a wish that he should apply himself to theology; but his genius had taken a different direction, and he was averse to the profession of an ecclesiastic: in short, young Default declared that he was determined to betake himself to the study of the healing art; and, after a long and ineffectual resistance on the part of his family, he was sent to Bésfort, in order to serve an *apprenticeship*, as it was then termed, in the military hospital of that place. He accordingly spent three years there; during which he acquired some knowledge of anatomy, attended to the dressing of the patients, and endeavoured to supply, by his own observations, what was wanting in his instruction.

In the midst of these professional labours, his mind frequently rambled towards another science but little connected with surgery: this was mathematics, the elements of which he had acquired among the Jesuits. His progress in this favourite study was rapid; but he fell into one of the many errors so common among the physicians of that day; this consisted in a false application of the rules of geometry to the laws of the animal economy.

He not only perused with avidity the treatise of Borelli *De Motu Animalium*, but actually translated the whole of it, and even added a commentary, still more abundant in calculation than that of the celebrated professor of Naples.

His success in a branch of physiology so much cultivated at that time, attracted the attention of one of his superiors, a zealous partizan of the doctrine of the mechanicians, who wished to attach him to his person; but his desire of fame required a more extensive theatre, and his love of study made him solicitous of better means of instruction. Paris presented both these advantages; and he accordingly repaired thither in 1764, at the age of nineteen, in search of them.

Surgery at that period flourished in the capital under the auspices of a Lafaye, a Morand, an Andouillet, and a Louis. The sight of such great masters excited the genius of those who aspired to emulate them: young Default deemed himself worthy of equalling men whom other students were content with only admiring. Animated by this sentiment, he entirely resigned himself to his ardour; anatomy became the special object of his labours, and his dissections were not confined to the human body, for he investigated, by means of his knife, a prodigious number of animals of all kinds: at first, from a difficulty of procuring human subjects, and afterwards on account of the advantages which he experienced from this general method. In order to become intimately acquainted with our own organization, it is necessary to compare it with whatever has a resemblance to it in other bodies.

He accordingly spent the greater part of the day in the amphitheatres. The hours stolen from his favourite labours were employed in attending the hospitals; he was the first at the bed of the patient where an operation was to be performed, and was sure to be present at the dressings, on purpose to examine the result. The infirmities of mankind, sterile in respect to the vulgar, served him as the best treatise for curing them; and the great surgeons of all nations have formed their mode of practice by contemplating the same book.

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Default.

But he reckoned too much on a robust and vigorous temperament; for, after two years close and assiduous application, he fell into a cachectical habit of body, which had nearly proved mortal, and which confined him for almost twelve months to his bed; but at length, owing partly to the vigour of his youth, and partly to the attention of his young friend Chopart, his inseparable companion in his operations, who attended him also during his last illness, and only survived him a few days, he was so fortunate as to recover.

Restored to life, he forgot that an excess of attention had conducted him to the very gates of death; a new career opened to his view, and required new efforts on his part. In the winter of 1766 he commenced a course of anatomy, and soon reckoned 300 pupils, most of them older than himself, who were attracted by the clearness of his demonstrations, the methodical arrangement of his descriptions, and, above all, by his indefatigable zeal in the science of instruction.

His success inspired the privileged professors, whose schools became deserted, with jealousy and revenge; they employed the authority of the corporation against him, and would have nipped his efforts in the bud, had it not been for the protection of Louis and Lamartiniere, who were zealous of protecting a youth of talents, whose sole reproach was, that he had not wealth enough to purchase certain franchises. After all, had it not been for the permission he obtained of borrowing the name of a celebrated physician, he must have actually desisted from his lectures.

Default's reputation now began to be buzzed about, and a multitude of patients claimed his assistance; but he constantly refused to practise until he should be placed at the head of some great establishment.

At length, at the repeated solicitations of his friends, he presented himself as a candidate to the corporation of surgeons; and they, much to their honour, admitted him in 1776, on condition of paying the usual fees when convenient. The following is the title of his thesis: "*De calculo vesicæ urinariæ, eoque extrahendo, præviâ sectione, ope instrumenti Haukenfsiani emendati.*"

His public lectures were accompanied with as much celebrity as his private ones. Brilliant discoveries were not the object of his anatomical labours, which were always connected with the art of healing: he was, however, the first man in France who taught surgical anatomy.

After becoming first a simple member, and then a counsellor, of the perpetual committee of the academy of surgery, he was appointed chief surgeon to the hospital of the college, and consulting surgeon to that of St Sulpice: neither of these added any thing to his fortune, but they gave him a clear insight into practice, and enabled him to judge of cases by the inductions arising from his own experience.

In 1779 he invented the bandage now in use for fractures; by means of which, the fragments being kept in a state of perpetual contact, become consolidated, without the least appearance of deformity, an almost inevitable consequence of the former mode.

On his appointment to the place of surgeon major to the hospital *de la Charité*, in 1782, he introduced a new method of treatment in oblique fractures of the thigh-bone; and he also healed, by means of a methodical compression, those various ulcers whose cure had hitherto been attended with great difficulty. In addition to this, he substituted new bandages in fractures of the humerus and clavicle, and adopted a new mode of treating the hare-lip, superior to that used by Louis. He never recurred to amputation but in extreme cases, when there was a certainty that dissolution would have followed a neglect of the operation.

When a premature death carried off Ferrand; chief surgeon of the *Hotel Dieu* in Paris, Default was considered as the most proper person to succeed him; and, on the demise of Moreau, the whole charge of the hospital devolved on him. After three years of solicitations and disputes, he at length in 1788 proceeded in his long projected scheme of establishing a clinical school; and a spacious amphitheatre was accordingly erected for that purpose. Scarcely had his first (A) course commenced, when the number of pupils who flocked around him was really astonishing. Foreigners repaired from all parts, and several of the neighbouring states sent students to Paris, expressly for the purpose of assisting at his demonstrations. More than 600 auditors constantly attended, in order to learn a new system, consisting of a simple mode of treatment, disengaged from ancient prejudices, and a complex incoherent practice.

A few of his improvements are here specified.

1. The method of ligature employed by the ancients in the cure of umbilical hernias of children, having been generally omitted in the practice of the moderns, he again introduced and perfected this mode, and demonstrated, by his success, its superiority over compressive bandages.

2. He was one of the first men in France to extract the loose cartilages (*cartilages flottans*) in joints.

3. He employed a new treatment, that of a methodical compression, in respect to schirrosities of the rectum; in order to which he introduced a candle or bougie, the size of which he gradually augmented.

4. He simplified, and rendered more commodious, the reduction of luxations of the humerus.

5. Fatal experience having pointed out the danger of employing the trepan in wounds of the head, he substituted another method of treatment (*l'usage de l'émétique*) now adopted by many practitioners.

6. He made several very useful improvements on surgical instruments; such as those employed in the cases

Default.

(A) The business of the day was conducted in the following routine: 1. A public consultation concerning the indigent out-patients. 2. The young practitioners belonging to the hospital read a detailed account of all the interesting cases of such patients as were to be discharged that day. 3. The operations: each of these was preceded by a dissertation on the state of the patient, who was then carried to the amphitheatre, where Default, attended by his assistants, performed the operation in presence of all the pupils. 4. Argumentative details, by the professor, either on the dangerous maladies existing in the hospital, or on the situation of the patients on whom operations had been performed during the preceding day. 5. The dissection of subjects. And, 6. A lecture on some particular branch of pathology.

Def nit.

cases of polypos in the womb and nostrils (*la pince à gaine et des porte-nœuds pour la ligature des polypes, &c.*;) for cutting through obstructions in the different cavities (*le kiotome*); and for the *fistula in ano*. In cases of incision he introduced the use of the instrument (*le gorgere*) invented by Marchetti, well known among foreigners, but almost totally neglected in France before this period.

He at the same time retrenched the use of a great number of superfluous ones, and banished all practices attended with greater pain than utility. Avoiding every thing that was complex, he proved that the art of healing, in imitation of nature, ought to be simple in its means, and fruitful in its resources.

In 1791 he published his *Journal de Chirurgie*, which was edited by his pupils, and destined to describe the most interesting occurrences in his school, and also extracts from his lectures, which were then dedicated to the investigation of the maladies incident to the urinary passages. The treatment of these diseases, hitherto the reproach of practitioners, had been much improved by the assistance of the artist Bernard. The elastic probes (*les sondes élastiques*), on their first appearance, fixed the attention of all professional men; but none knew better than Default how to appreciate their advantages. By means of them, he introduced a novel mode of cure in contractions of the urethra, which saved a great number of lives every year in the *Hotel-Dieu*. But he did not confine their use to the diseases of the urethra alone, for he employed them to remove the divers obstacles that impede deglutition or respiration.

In the midst of such a multiplicity of labours, and although he was obliged to attend 400 sick twice a day, Default nevertheless employed more than four hours of his time in visiting private patients.

Few surgeons ever enjoyed such an exclusive share of public confidence; few ever possessed similar means of enriching themselves; and yet he neglected for a long time to take advantage of this. Had he been less ardent for glory, he would have been more favoured by fortune; but he sacrificed all interested views to the noble ambition of advancing his art. His clinical and anatomical courses were gratuitously opened by him to the world after the year 1790; and while the public schools languished in the midst of troubles, inseparable perhaps from a mighty revolution, he was forming the greater part of those surgeons employed at this present moment in the numerous armies of the republic. Considered under this point of view alone, the services which he rendered to humanity are incalculable: too happy if persecution had not been his sole reward!

While out of mere attachment to the public weal, he added to his various functions that of a member of the council of health, conferred on him in 1792 by the minister Servan, he was denounced in the popular societies as an *egotist*, an *indifferent*, &c. and became one of the first victims of that proscription which, under Robespierre, extended to nearly every man of talents.

Chaumette accused him to the sections as having neglected the brave men wounded on the 10th of August, while they themselves were lavishing their blessings at the *Hotel-Dieu* on their favour. Twice was he brought to the bar of a commune; desirous of discovering a pretext for persecution, the clamours of the people were

unremittingly excited against him. He was at length carried away from his amphitheatre, while in the very act of haranguing his pupils; and, in consequence of a *mandat d'arrêt* from the revolutionary committee, conducted by a body of armed men to the Luxembourg. From this horrid prison few ever departed but to meet their fate; luckily, however, his name was not yet entered on that bloody list, in which those of Maleherbes and Lavoisier were inserted. On the contrary, at the end of three days he was liberated, and instantly resumed all his functions.

On the establishment of *L'Ecole de Santé*, Default was appointed clinical professor; and for external maladies he soon after obtained from the government the conversion of the *Eveché* into an hospital for surgical operations.

In the midst of these plans, the troubles that occurred in the month of May unfortunately affected his mind, and made him dread lest the days of proscription should return. It was in vain that his friends attempted to soothe his sufferings; for on the night of the 29th of May, a malignant fever made its appearance, and a nearly continual delirium ensued until his death, which occurred on the 1st of June 1795, on which day he breathed his last, in the arms of his pupils, at the age of 51.

The populace were persuaded that he was poisoned. This ridiculous opinion originated in consequence of the epoch of his death, which preceded but a short time that of the son of Louis XVI. whom he had visited during his illness in the prison of the Temple. It is pretended that he fell a victim to his constant refusal to yield to the criminal views entertained against the life of that child.

Default was of a middling stature. He was well proportioned, and possessed an open countenance. His temperament, naturally robust, had been fortified by his early education, and was never sapped by an excess of pleasures, for to them his heart was always indifferent. His ruling passion was the love of glory; his favourite pursuit, the practice and advancement of his art. He was warm, nay sometimes violent; and his scholars were not always inclined to praise the sweetness of his temper. On the other hand, his mind was noble, elevated, and great, even to excess.

The French republic, eager to pay homage to his memory, has presented his widow with a pension of 2000 livres *per annum*. A son, Alexis Mathias Default, was the sole fruit of his marriage; and he has left but one work behind him, in which the name of his friend Choquet is joined with his own. It is entitled *Traité des Maladies Chirurgicales et des Operations qui leur conviennent*, 2 vols 8vo.

DETERMINATE PROBLEM, is that which has but one solution, or a certain limited number of solutions; in contradistinction to an indeterminate problem, which admits of infinite solutions.

DETERMINATE SECTION, the name of a tract or general problem, written by the ancient geometrician Apollonius. None of this work has come down to us, excepting some extracts and an account of it by Pappus, in the Preface to the 7th book of his *Mathematical Collections*. He there says that the general problem was, "To cut an infinite right line in one point so, that, of the segments contained between the point of section

Default, Determinate.

Detona-
tion.

section fought, and given points in the said line, either the square on one of them, or the rectangle contained by two of them, may have a given ratio, either to the rectangle contained by one of them and a given line, or to the rectangle contained by two of them."

DETONATION (see that word *Encycl.*). The astonishing violence with which the oxy-muriat of potass, when mixed with various substances, detonates, has been already noticed in this Supplement under the article **CHEMISTRY**, n^o 722, where the theory of these explosions is likewise given. But as several chemists seem to think that this salt, which decrepitates by friction, and spontaneously takes fire when mixed with sulphur, contains in itself the elements and phenomena of thunder, it will not probably be unacceptable to our readers to find, in this place, a distinct account of the various mixtures which produce its detonations. The following are the principal which have been discovered by Fourcroy and Vauquelin.

1. Three parts of the oxy-muriat of potass, and one part of powdered sulphur, rubbed together in a metal mortar, produce numerous successive explosions, resembling the smacking of a whip, or even as loud as the report of a pistol or a musket, according to the rapidity of the motion, and the force of the pressure made use of. A few grains of the same mixture, by being struck smartly upon an anvil with a hammer, occasion a report equal to that of a musket; and torrents of purplish light are seen about the anvil. If this mixture be thrown into concentrated sulphuric acid, it instantly takes fire, and burns, without noise, with a flame of a dazzling whiteness.

2. A mixture of three parts of this salt, half a part of sulphur, and half a part of charcoal, causes stronger explosions than the preceding when rubbed in a mortar, and a louder noise when struck upon an anvil. Its flame also, when the mixture is made to explode, or when it is thrown into sulphuric acid, is more rapid, more lively, and of a redder colour, than that of the preceding.

3. A mixture of equal parts of oxy-muriat of potass and antimony in powder explodes with noise by percussion; but produces only reddish sparks when thrown into sulphuric acid. If zinc be substituted in the place of antimony, a similar explosion takes place, accompanied with a white flame. Sulphuric acid has no effect upon this last mixture.

4. With regulus of arsenic, this salt explodes very violently by the stroke of a hammer; it inflames, with singular rapidity and brilliancy, by the contact of sulphuric acid. In this last experiment there arises a smoke, which in the air takes the form of a crown, in the same manner as phosphorated hydrogenous gas does when it inflames spontaneously in a still atmosphere.

5. Sulphuret of iron or martial pyrites inflames rapidly, but without noise, when rubbed in a metal mortar with oxy-muriat of potass. This mixture, when struck upon an anvil, explodes violently, and with a red flame.

6. The red sulphuret of mercury or cinnabar, and the sulphurated calces of antimony, explode with the oxy-muriat of potass by percussion, but they do not inflame by sulphuric acid. The same thing happens when charcoal alone is mixed with this salt.

Any of the following substances, namely, sugar, gums,

oils (both fixed and volatile), alcohol, ether, when mixed with oxy-muriat of potass, have the property of exploding very violently by the stroke of a hammer, and all of them send forth a brisk flame at the time of their explosion. The liquid combustible substances above mentioned are to be mixed with the salt in such a manner as to form a kind of paste. None of these mixtures explode or inflame by being rubbed in a mortar; but some of them inflame by being mixed with concentrated sulphuric acid, their combustion being slow and progressive.

8. All the substances above mentioned, which, being mixed with the oxy-muriat of potass, take fire and burn instantly, and with considerable noise, by the quick pressure of the strokes of a hammer, produce a much stronger explosion when they are so closely wrapped up in paper, two or three times doubled, as to be thereby compressed before they are struck.

9. An electric shock from a battery of large surface, charged by a strong electric machine, causes all the fore-mentioned mixtures to explode in the same manner as percussion, and their explosion is also accompanied by a bright light.

To the above mentioned facts, the authors add, that it was already well known that gunpowder would explode by a violent blow, or very strong pressure; but they observe, that the stroke which is necessary for that purpose must be much stronger than that which suffices to produce an explosion in the above-mentioned mixtures of combustible substances with the oxy-muriat of potass; and that its explosion is by no means so remarkable as that which is produced by the help of this new salt.

DEWAN, under the Mogul government, the receiver general and civic governor of a province: in private life a steward.

DEWANNY, the revenue department of a province.

DIABETES MELLITUS (see **MEDICINE**, n^o 318, &c. *Encycl.*), is so formidable a disease, though not very frequent, that it would be unpardonable in us not to mention every method of treating it successfully which has come to our knowledge. Since our article **MEDICINE** was published, Dr Rollo, surgeon general to the royal artillery, has suggested a method of treating this disease, which in various instances has been crowned with success.

The Doctor supposes, that in this complaint the vegetable matter taken into the stomach has not, from some defect in this organ, undergone a sufficient change to form proper chyle; that in consequence of this, much saccharine matter is evolved, which, when carried into the circulation, proves a general stimulus, producing head-aches and quickness of pulse, but that it acts more remarkably on the kidneys, occasioning a constant and copious secretion of sweet urine. From this hypothesis, he was naturally led to adopt a plan of cure, which has proved completely successful. The indications he lays down are: 1. To prevent the formation of saccharine matter in the stomach; and, 2. To remove the morbidly increased action of this organ, and restore it to a healthful condition. These indications are to be answered by a complete diet of animal food, and by the use of such medicines as shall diminish the action of the stomach,

Detona-
tion
||
Diabetes.

Diamond,
Diderot.

stomach, and at the same time counteract the formation of saccharine matter. The remedies employed for this purpose have been emetics, kali sulphuratum, lime-water, hepatic ammonia, and vegetable narcotics. But the principal dependence is to be placed on a total abstinence from all vegetable matter, which alone can supply the saccharine principle. By a regular perseverance in this plan, the first of two patients was completely cured in four weeks, although the disease had been of seven months continuance. The urine, which at the commencement of the treatment was sweet, and amounted to 24 pints daily, was at last reduced to 1½ pint, being at the same time free from any saccharine impregnation. The second patient, from his age and other circumstances, although relieved from the diabetic affection, did not regain his wonted state of health; but even in this case, the effects produced by the treatment, when properly attended to, were most decidedly in confirmation of this plan of cure.

The Doctor has received several communications in consequence of the dispersion of the printed notes on the first case. The most important are the result of two cases treated in this way by Dr Cleghorn of Glasgow, and one by Drs Currie and Gerard at Liverpool; all of which afford the strongest corroboration of the efficacy of this mode of treatment.

DIAMOND, the most precious of all the gems; for the nature of which see CHEMISTRY, n° 33, &c. in this Supplement.

DIDEROT (Dionysius) of the academy of Berlin, the son of a cutler, was born at Langres in 1713. The Jesuits, with whom he went through a course of study, were desirous of having him in their order; and one of his uncles, designing him for a canonry which he had in his gift, prevailed upon him to take the tonsure.

His father seems to have known him better; for perceiving that he was not inclined to be a Jesuit, nor fit to be a canon, he sent him to Paris to prosecute the study of the law. To the law, however, he paid very little attention, but devoted his time to science and general literature; which so offended his father, that he stopped the remittance of his pecuniary allowance, and seemed for some time to have abandoned him.

The talents of young Diderot supplied him with a maintenance, and drew him from obscurity. According to his friends, his capacious mind embraced physics, geometry, metaphysics, ethics, and the belles lettres, from the time that he began to read with reflection; and it is certain that he aspired at being a master in all these departments of literature. His bold and elevated imagination seemed to give him likewise a turn for poetry; but he neglected it for the sciences. He settled at an early period at Paris, where the natural eloquence which animated his conversation procured him friends and patrons. What first drew the attention of the public to him as an author, and gave him a high reputation among a certain class of readers, was a small volume written against the Christian religion, and intitled *Pensées Philosophiques*; which was reprinted afterwards under the title of *Etrennes aux Esprits-forts*.

This book appeared in 1746, 12mo. The adepts of the new philosophy compared it, for perspicuity, elegance, and force of diction, to the *Pensées de Pascal*. But the aim of the two authors was widely different; Pascal employed his talents and his erudition, which

was profound and various, to support and illustrate the great truths of our holy religion, which Diderot attacked by all the disingenuous arts of an unprincipled sophist. The *Pensées Philosophiques*, however, became popular. It contributed to promote the object of that conspiracy which had been for some time formed against every thing which ennobles human nature (See JACOBS in this Supplement). It was therefore applauded by Voltaire and D'Alembert, and read, of course, by every man and woman of taste in Paris.

Our author was more usefully employed in 1746, when, together with Messrs *Eidous* and *Touissant*, he published a general Dictionary of Medicine, in six volumes folio. This work, it must be confessed, has considerable merit; for though there are in it several articles superficial and erroneous, there are many others of such deep and accurate disquisition, as deservedly recommended it to men of science.

It was about this time that an intimacy was formed between Diderot and D'Alembert, and that, under the direction of Voltaire, they formed the idea of a *Dictionnaire Encyclopedique*. The great objects which they had in view when they entered upon this work are now universally known. D'Alembert was a profound mathematician, Diderot had considerable knowledge in the physical sciences, more especially mechanical philosophy, and Voltaire was a master of the belles lettres.

It is not to be supposed that such men would publish any thing very defective in these departments of science; but an *Encyclopaedia* must treat of religion; and to every kind of religion they were all sworn enemies. They engaged, however, a very worthy, though not very acute, clergyman, to furnish the theological articles; and for other branches of knowledge, they were promised the assistance of several men of letters, and of a variety of artists.

Diderot took upon himself the description of arts and trades; one of the most important departments of the work, and the most acceptable to the public. To the particulars of the several processes of the workmen he sometimes added reflections, speculations, and principles, adapted to the elucidation. But besides his own department, he furnished articles on almost every other subject.

By those who knew not the great aim of the undertakers of this work, it has been regretted that Diderot was not less verbose, less of the dissertator, and less inclined to digressions. He has also been censured for employing needlessly a scientific language, and for having recourse to metaphysical doctrines, frequently unintelligible, which occasioned him to be called the *Lycophron of philosophy*; for having introduced a number of definitions incapable of enlightening the ignorant, and which the philosopher seems to have invented for no other purpose than to have it thought that he had great conceptions; while, in fact, he had not the art of expressing perspicuously and simply the ideas of others. But these complaints arise from mistaking entirely the purpose for which he wrote.

It has been completely proved, that one great object for which the philosophers, as they called themselves, undertook the compilation of the *Encyclopedie* was to sap the foundation of all religion. This was to be attempted, not directly and avowedly; for bare-faced atheism would not then have been suffered in France.

Diderot.

Diderot. A cloak, therefore, was to be worn, and the poisoned dagger to be concealed under it. Whilst the well-meaning divine was supporting, by the best arguments which he could devise, the religion of his country, Diderot and D'Alembert were overturning those arguments under titles which properly allowed of no such disquisitions. This necessarily produced digressions; for the greatest genius on earth could not, when writing on the laws of motion, attack the mysteries of Christianity without wandering from his subject; but that the object of these digressions might not pass unnoticed by any class of readers, care was taken to refer to them from the articles where the question was discussed by the divine. That when employed in this way, Diderot seems to write obscurely, is indeed true; but the obscurity is not his. His atheism was so plain, that for the most part D'Alembert, or some other leader of the gang, had to retouch his articles, and throw a mist over them, to render their intention the less obvious.

Even with all this care and studied obscurity, the design of the *Encyclopedie* was too palpable not to be seen, and too wicked not to give offence. Certain wild positions on government and on religion occasioned the impression to be suspended in 1752. At that time there were no more than two volumes of the dictionary published; and the prohibition of the succeeding ones was only taken off at the end of 1753. Five new volumes then successively appeared. But in 1757 a new storm arose, and the book was suppressed. The remainder did not appear till about ten years after; and was then for a while only privately distributed; some copies having been seized by government, and the printers shut up in the Bastille. The merit, however, of some of the articles is confessedly great; and the first edition was quickly sold off.

Thus was this great work in the press from 1751 to 1767; during which period, Diderot and D'Alembert were accustomed to frequent the coffee-houses of Paris, and to enter with keenness into religious disputes: the former attacking Christianity; and the latter, under the mask of piety, defending it; but always yielding to the arguments of his opponent. This practice was put a stop to by the police; and Diderot, when reproached by the lieutenant with preaching atheism, replied, "Cela est vrai, je suis athée, & m'en fais gloire."

Finding his impious conversations interrupted, and the publication of the *Encyclopedie* rendered tedious by the vigilance of government, he thought of propagating his notions by other vehicles. Alternately serious and sportive, solid and frivolous, he published, at the very time he was working on the Dictionary of Sciences, several productions, which could scarcely have been expected from a man so completely employed. His *Bijoux Indiscrets*, 2 vols 12mo, are of this number—a disgusting work, even to those young people who are unhappily too eager for following after licentious romances. Even here a certain philosophical pedantry appears in the very passages where it is most misplaced, and never is the author more awkward than where he intends to display a graceful ease.

The *Fils Naturel*, and the *Pere de Famille*, two comedies in prose, which appeared in 1757 and 1758, are not of the same kind with the *Bijoux Indiscrets*. They are moral and affecting dramas, where we see at once a nervous style and pathetic sentiments. The former piece

is a picture of the trials of virtue, a conflict between interests and passions, wherein love and friendship play important parts. It has been said that Diderot borrowed it from Goldoni: but if that be the case, the copy does honour to the original; and, with the exception of a small number of scenes, where the author mixes his philosophical jargon with the sentiments of the heart, and some sentences out of place, the style is affecting and natural enough. In the second comedy, a tender, virtuous, and humane father appears, whose tranquillity is disturbed by the parental solitudes, inspired by the lively and impetuous passions of his children. This philosophical, moral, and almost tragical comedy, has produced considerable effects on several theatres of Europe. The dedication, to the princess of Nassau Saarbuck, is a little moral tract of a singular turn, without deviating from nature. This piece, written with a true dignity of style, proves that the author possessed a great fund of moral sentiments and philosophical ideas. At the end of these two pieces, published together under the title of *Theatre de M. Diderot*, are dialogues, containing profound reflections and novel views of the dramatic art. In his plays he has endeavoured to unite the characters of Aristophanes and Plato; and in his reflections he sometimes displays the genius of Aristotle.

This spirit of criticism is exhibited, but with too much licence, in two other works, which made a great noise. The former appeared in 1749, 12mo, intitled *Letters on the Blind for the Use of those who See*. The free notions of the author in this work cost him his liberty. He underwent a six months imprisonment at Viorcennes. Having naturally strong passions and a haughty spirit, and finding himself on a sudden deprived of liberty and of all intercourse with human beings, he was threatened with the loss of his reason. The danger was great; and to prevent it, they were obliged to allow him to leave his room, to take frequent walks, and to receive the visits of a few literary men; among whom J. J. Rousseau, at that time his friend, went and administered consolation to him, which he ought not to have forgotten.

The letter on the Blind was followed by another *On the Deaf and Dumb, for the Use of those who can Hear and Speak*; 1751; 2 vols, 12mo. Under this title the author delivered reflections on metaphysics, on poetry, on eloquence, on music, &c. In this essay there are some good things, among others absurd and imperfect. Though he strives to be perspicuous, yet he is not always understood; and this is more his fault than that of his readers. Of what he has composed on abstract subjects, it has been said that it is a chaos on which the light shines only at intervals. The other productions of Diderot betray the same defect of clearness and precision, and the same uncouth emphasis, for which he has always been blamed.

The principal of them are, 1. Principles of Moral Philosophy, 1745, 12mo; of which the Abbé de Fontaine speaks well, though it met with no great success. It was our philosopher's fate to write a great deal, and not to leave a good book, or at least a book well composed. 2. History of Greece, translated from the English of Stanyan, 3 vols, 12mo; an indifferent translation of an indifferent book. 3. Pieces on several Mathematical Subjects, 1748, 8vo. 4. Reflections on the

Diderot. Interpretation of Nature, 1754, 12mo. This interpreter is very obscure. 5. The Code of Nature, 1755, 12mo; which is certainly not the code of Christianity. 6. The Sixth Sense, 1752, 12mo. 7. Of Public Education; one of that swarm of publications produced by the appearance of Emelius, and the abolition of the Jesuits. Though all the ideas of this author could not be adopted, yet some of them are very judicious, and would be highly useful in the execution. 8. Panegyric on Richardson. Full of nerve and animation. 9. Life of Seneca. This is the last work which he acknowledged; and it is one of those by Diderot that is perused with most pleasure, even in rectifying the judgments he passes on Seneca and other celebrated men. The Abbé Barruel says, that he was the author of *Système de la Nature*, which is usually given to Robinet; and it is certain, that if he was not the author, he furnished hints, and revised the whole. Yet the junto of atheists were themselves ashamed of the first edition of that work; and after all Diderot's care to improve it, the subsequent editions are, notwithstanding his boasted knowledge of the laws of nature, contemptible in the eyes of a real mechanical philosopher.

When a new edition of the *Encyclopedie* was resolved on, Diderot, the editor of the former edition, thus addresses the booksellers who had undertaken to republish it. "The imperfections (says he) of this work originated in a great variety of causes. We had not time to be very scrupulous in the choice of our coadjutors. Among some excellent persons, there were others weak, indifferent, and altogether bad. Hence that motley appearance of the work, where we see the rude attempt of the school-boy by the side of a piece from the hand of a master; a piece of nonsense next neighbour to a sublime performance. Some working for no pay, soon lost their first fervour; others, badly recompensed, served us accordingly. The *Encyclopedie* was a gulf into which all kinds of scribblers promiscuously threw their contributions; their pieces ill conceived, and worse digested, good, bad, contemptible, true, false, uncertain, and always incoherent and unequal; the reference that belonged to the very parts assigned to a person, never filled up by him. A reputation is often found where we should naturally expect a proof. There was no exact correspondence between the text and the plates. To remedy this defect, recourse was had to long explanations. But how many unintelligible machines, for want of letters to denote the plates!" To this confession Diderot added particular details on various parts; such as proved that there were in the *Encyclopedie* subjects to be not only retouched, but to be composed afresh; and this was what a new company of literati and artists set themselves to work upon in the *Encyclopedie Methodique*.

This immense work is not yet completed; and therefore we cannot speak of it as a whole; but it is surely not less verbose than the former edition, nor do the aims of its editors appear to be purer. That it contains much valuable information in chemistry, and indeed in every department of physical science, no candid man will controvert: but its articles on abstract philosophy are prolix and obscure; and it betrays the same impiety, the same eager desire to corrupt the principles of the rising generation, and the same contempt for every

thing which can make mankind happy here or hereafter, with the former edition. Diderot,

Notwithstanding his numerous publications, Diderot was never rich. Soon after the publication of the last volumes of the *Encyclopedie*, upon which he had been employed for upwards of twenty years, his circumstances were so straitened, that an expedient was to be devised for their improvement. He had long corresponded with the late Empress of Russia, whom he persuaded to consider him as the greatest, or one of the greatest economists of France. In the course of the correspondence he had mentioned his own library as one of the most valuable in Europe; and when Catharine wanted to purchase it and make him librarian, he said that his constitution could not support the cold climate of St Petersburg. She offered to let him keep it during his lifetime in Paris; and the library was sold for an immense price. When her ambassador wanted to see it, after a year or two's payments, and the visitation could be no longer put off, Diderot was obliged to run in a hurry through all the booksellers shops in Germany to fill his empty shelves with old volumes. He had the good fortune to save appearances; but the trick took air, because he had been niggardly in his attention to the ambassador's secretary. This, however, did not hinder him from visiting his imperial pupil, to whom he told a poor story, in hopes of getting his daughter married with parade, and patronised by her majesty; but it was seen through, and he was disappointed.

In the year 1784 Diderot's health began visibly to decline; and one of his domestics, perceiving that his death was at no great distance, acquainted him with his apprehensions, and addressed him on the importance of preparing for another world. He heard the man with attention, thanked him kindly, acknowledged that his situation required seriousness, and promised to weigh well what he had said. Some time after this conversation he desired that a priest might be brought; and the same domestic introduced to him M. de Farfac, Curé de St Sulpice. Diderot saw this ecclesiastic several times, and was preparing to make a public recantation of his errors. Condorcet and the other adepts now crowded about him, persuaded him that he was cheated, that his case was not so dangerous as it was said to be, and that he only wanted the country air to restore him to health. For some time he resisted their attempts to bring him back to atheism, but was at last prevailed upon to try the effect of the country air. His departure was kept secret, and he was concealed in the country till the 2d of July, when he died. His dead body was secretly brought back to Paris, and a report was spread and believed that he died suddenly on rising from the table, without remorse, and with his atheism unshaken.

To draw a formal character of this wretch is surely superfluous. His friends extol his frankness, his disinterestedness, and his integrity; but except his gross avowal of atheism, which may in France be called frankness, this character is belied by every transaction of his life. He married, and had a daughter, as has been already mentioned. M. Bauzé, referred to by Abbé Barruel, coming one day into Diderot's house, found him explaining to this daughter a chapter of the gospel. When he expressed some surprise at this conduct, Diderot said: "J'entends ce que vous voulez dire; mais

Differential
Method.

mais au fond, quelles meilleures leçons pourrois-je lui donner, ou trouverai-je mieux?" It was a common assertion of Diderot's, that between him and his dog "it n'y avoit de difference que habit." In uttering this sentiment, he resembled not Pope's Indian with untutored mind,

"Who thinks, admitted to that equal sky,
"His faithful dog shall bear him company."

The Indian hopes to carry his dog with him to heaven; but Diderot hoped to die like a dog, and to be as if he had never been.

DIFFERENTIAL METHOD, is the art of working with the differences of quantities. By this method any term of a series may be found from the several orders of differences being given; or *vice versa*, any difference may be found from having the terms of the series given: it likewise shews how to find the sum of such a series. And it gives rules to find by interpolation any intermediate term, which is not expressed in the series, by having its place or position given.

When any series of quantities is proposed, take the first term from the second, the second from the third, the third from the fourth, &c. then all these remainders make a new series, called the *first order of differences*. In this new series take the first term from the second, the second from the third, the third from the fourth, &c. as before; and these remainders make another series, called the *second order of differences*. In like manner, in this series, take the first term from the second, the second from the third, &c.; and these will make a series called the *third order of differences*; and after this manner you may proceed as far as you will. Thus in the following proposition *A, b, c, d, e, &c.* is the series; *B, B², B³, B⁴, &c.* the first order of differences; *C, C², C³, &c.* the second order of differences; *D, D², &c.* the third order; *E, &c.* the fourth order, and so on. But the first terms of these several orders of differences, as *B, C, D, E, &c.* are those that are principally made use of in calculations by this method.

PROP. I. If there be any series, *A, b, c, d, e, &c.* and if there be taken the first differences *B, B², B³, &c.* the second differences *C, C², C³, &c.* the third differences *D, D², D³, &c.* and so on.

Then if *T* stand for the first term of the *n*th differences, $\pm T = A - nb + n \times \frac{n-1}{2}c - n \times \frac{n-1}{2} \times \frac{n-2}{3}d + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4}e - \&c.$ that is, $+T$, when *n* is even, and $-T$ when *n* is odd.

The several orders of differences being taken as before directed, will stand thus. Then,

A	B	C	D	E
b	B	C	D	E
	B ²	C ²	D ²	
	c	B ³	C ³	
	d	B ⁴	&c.	
e				

series	A	b	c	d	e	&c.
1st diff.	b-A	c-b	d-c	e-d	&c.	
2d diff.		c-2b+A	d-2c+b	e-2d+c	&c.	
3d diff.			d-3c+3b-A	e-3d+3c-b	&c.	
4th diff.				e-4d+6c-4b+A	&c.	

That is, $B = b - A, C = c - 2b + A, D = d - 3c + 3b - A, E = e - 4d + 6c - 4b + A, \&c.$ or $-B = A - b, +C = A - 2b + c, -D = A - 3b + 3c - d, +E = A - 4b + 6c - 4d + e, \&c.$ where, putting *T* successively equal to *B, C, D, E, &c.* and *n = 1, 2, 3, 4, &c.* the prop. will be evident.

Cor. Hence

- A = A, the first term.
- B = -A + b, the first difference.
- C = A - 2b + c, the 2d difference.
- D = -A + 3b - 3c + d, the 3d difference.
- E = A - 4b + 6c - 4d + e, the 4th difference.
- F = -A + 5b - 10c + 10d - 5e + f, the 5th difference, &c.

PROP. II. If *A, b, c, d, e, &c.* be any series, and there be taken *B, C, D, E, &c.* the first of the several orders of differences;

Then, the *n*th term of the series will be $= A + \frac{n-1}{1}B + \frac{n-1}{1} \times \frac{n-2}{2}C + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3}D + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4}E + \&c.$

For from the equations in the last Prop. viz $B = b - A, C = c - 2b + A, \&c.$ we have, by transposing, $b = A + B, = -A + 2b + C = -A + 2A + 2B + C$ (expunging *b*); that is, $c = A + 2B + C, d = A - 3b + 3c + D = A - 3A - 3B + 3A + 6B + 3C + D$ (expunging *b* and *c*); that is, $d = A + 3B + 3C + D.$ Also $e = -A + 4b - 6c + 4d + E =$ (expunging *b, c, d*) $-A + 4A + 4B - 6A - 12B - 6C + 4A + 12B + 12C + 4D + E;$ that is, $e = A + 4B + 6C + 4D + E, \&c.$

Then putting *A, b, c, d, &c.* for the *n*th term, and *n* successively = 1, 2, 3, 4, &c. the series will be evident.

Cor. 1. If *d, d', d'', &c.* be the first of the first, second, third order, &c. of differences; then

The *n*th term of the series *A, b, c, d, &c.* will be $= A + \frac{n-1}{1}d + \frac{n-1}{1} \times \frac{n-2}{2}d'' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3}d''' + \frac{n-1}{1} \times \frac{n-2}{2} \times \frac{n-3}{3} \times \frac{n-4}{4}d^{iv} + \&c.$

For $B = d', C = d'', D = d''', \&c.$ And the coefficients are the unciæ of the *n - 1*th power.

Cor. 2. Hence also it follows, that any term of a given series may be accurately determined, if the differences of any order happen at last to be equal.

Cor. 3. Hence

- A = A, the first term.
- b = A + B, the 2d term.
- c = A + 2B + C, the 3d term.
- d = A + 3B + 3C + D, the 4th term.
- e = A + 4B + 6C + 4D + E, the 5th term.
- f = A + 5B + 10C + 10D + 5E + F, the 6th term.
- g = A + 6B + 15C + 20D + 15E + 6F + G, the 7th term, &c.

PROP. III. If *a, b, c, d, e, &c.* be any series, and $d', d'', d''', \&c.$ the first of the several orders of differences; then

The sum of *n* terms of the series is $= na + n \times \frac{n-1}{2}d' + n \times \frac{n-1}{2} \times \frac{n-2}{3}d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4}d''' + \&c.$

Differential
Method.

Diffraction
||
Direct.

$$\times \frac{n-3}{4} d'' + n \times \frac{n-1}{2} \times \frac{n-2}{3} \times \frac{n-3}{4} \times \frac{n-4}{5} d''' + \&c.$$

For in the series of quantities,

0, a, a+b, a+b+c, a+b+c+d, &c.
1st diff. are a, b, c, d, &c.
2d diff. d', d'2, d'3, &c.
3d diff. d'', d''2, &c.
4th diff. d''', &c.

Therefore (by Cor. 1. Prop. II.) the $n+1$ th term of the series, 0, a, a+b, a+b+c, a+b+c+d, &c. or the n th term of the series, a, a+b, a+b+c, a+b+c+d, &c. is $= 0 + na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + \&c.$ But the n th term of the series a, a+b, a+b+c, &c. is the sum of n terms of the series, a, b, c, d, &c. and therefore equal to $na + n \times \frac{n-1}{2} d' + n \times \frac{n-1}{2} \times \frac{n-2}{3} d'' + \&c.$

For a fuller account of this method, and its application to curves, we refer the reader to Emerson's works, from which these three propositions are taken.

DIFFRACTION, a term first used by Grimaldi, to denote that property of the rays of light which others have called inflection; the discovery of which is attributed by some to Grimaldi, and by others to Dr Hook.

DIMINUTION, in music, is the abating something of the full value or quantity of any note.

DIOPHANTUS, a celebrated mathematician of Alexandria, has been reputed to be the inventor of algebra; at least his is the earliest work extant on that science. It is not certain when Diophantus lived. Some have placed him before Christ, and some after, in the reigns of Nero and the Antonines; but all with equal uncertainty. It seems he is the same Diophantus who wrote the Canon Astronomicus, which Suidas says was commented on by the celebrated Hypatia, daughter of Theon of Alexandria. His reputation must have been very high among the ancients, since they ranked him with Pythagoras and Euclid in mathematical learning. Bachet, in his notes upon the 5th book De Arithmetica, has collected, from Diophantus's epitaph in the Anthologia, the following circumstances of his life; namely, that he was married when he was 33 years old, and had a son born five years after; that this son died when he was 42 years of age, and that his father did not survive him above four years; from which it appears that Diophantus was 84 years old when he died.

DIOPTER, or **DIOPTRA**, the same with the index or alidade of an astrolabe, or other such instrument.

DIOPTRA was an instrument invented by Hipparchus, which served for several uses; as, to level water-courses; to take the height of towers, or places at a distance; to determine the places, magnitudes, and distances of the planets, &c.

DIRECT, in arithmetic, is when the proportion of any terms, or quantities, is in the natural or direct order in which they stand; being the opposite to inverse, which considers the proportion in the inverted order of the terms. So, 3 : 4 :: 6 : 8 directly; or 3 : 4 :: 8 : 6 inversely.

DIRECTION, in astronomy, the motion and other phenomena of a planet when direct.

DIRECTION, in astrology, is a kind of calculus, by which they pretend to find the time in which any notable accident shall befall the person whose horoscope is drawn.

DISCRETE QUANTITY, is such as is not continued and joined together. Such, for instance, is any number.

DITTON (Humphry), an eminent mathematician, was born at Salisbury, May 29. 1675. Being an only son, and his father observing in him an extraordinary good capacity, determined to cultivate it with a good education. For this purpose he placed him in a reputable private academy; upon quitting of which he, at the desire of his father, though against his own inclination, engaged in the profession of divinity, and began to exercise his function at Tunbridge in the county of Kent, where he continued to preach some years; during which time he married a lady of that place.

But a weak constitution, and the death of his father, induced Mr Ditton to quit that profession. And at the persuasion of Dr Harris and Mr Whitton, both eminent mathematicians, he engaged in the study of mathematics; a science to which he had always a strong inclination. In the prosecution of this science he was much encouraged by the success and applause he received: being greatly esteemed by the chief professors of it, and particularly by Sir Isaac Newton, by whose interest and recommendation he was elected master of the new mathematical school in Christ's Hospital; where he continued till his death, which happened in 1715, in the 40th year of his age, much regretted by the philosophical world, who expected many useful and ingenious discoveries from his assiduity, learning, and penetrating genius.

Mr Ditton published several mathematical and other tracts, as below.—1. Of the Tangents of Curves, &c. Philos. Transf. vol. 23.

2. A Treatise on Spherical Catoptrics, published in the Philos. Transf. for 1705; from whence it was copied and reprinted in the Acta Eruditorum 1707, and also in the Memoirs of the Academy of Sciences at Paris.

3. General Laws of Nature and Motion, 8vo, 1705. Wolfius mentions this work, and says that it illustrates and renders easy the writings of Galileo, Huygens, and the Principia of Newton. It is also noticed by La Roche, in the Memoires de Literature, vol. viii. p. 46.

4. An Institution of Fluxions, containing the first Principles, Operations, and Applications, of that admirable Method, as invented by Sir Isaac Newton, 8vo, 1706. This work, with additions and alterations, was again published by Mr John Clarke, in the year 1728.

5. In 1709 he published the Synopsis Algebraica of John Alexander, with many additions and corrections.

6. His Treatise on Perspective was published in 1712. In this work he explained the principles of that art mathematically; and besides teaching the methods then generally practised, gave the first hints of the new method afterwards enlarged upon and improved by Dr Brook Taylor; and which was published in the year 1715.

Direction
||
Ditton.

7. In 1714, Mr Ditton published several pieces both theological and mathematical; particularly his Discourse on the Resurrection of Jesus Christ; and 'The New Law of Fluids, or a Discourse concerning the Ascent of Liquids, in exact Geometrical Figures, between two nearly contiguous Surfaces. To this was annexed a tract, to demonstrate the impossibility of thinking or perception being the result of any combination of the parts of matter and motion: a subject much agitated about that time. To this work also was added an advertisement from him and Mr Whiston, concerning a method for discovering the longitude, which it seems they had published about half a year before. This attempt probably cost our author his life; for although it was approved and countenanced by Sir Isaac Newton, before it was presented to the Board of Longitude, and the method has been successfully put in practice, in finding the longitude between Paris and Vienna; yet that board then determined against it: so that the disappointment, together with some public ridicule (particularly in a poem written by Dean Swift), affected his health so that he died the ensuing year, 1715.

In an account of Mr Ditton, prefixed to the German translation of his Discourse on the Resurrection, it is said that he had published, in his own name only, another method for finding the longitude; but which Mr Whiston denied. However, Raphael Levi, a learned Jew, who had studied under Leibnitz, informed the German editor, that he well knew that Ditton and Leibnitz had corresponded upon the subject; and that Ditton had sent to Leibnitz a delineation of a machine he had invented for that purpose; which was a piece of mechanism constructed with many wheels like a clock, and which Leibnitz highly approved of for land use; but doubted whether it would answer on ship-board, on account of the motion of the ship.

DIVING-BELL has been already described in the *Encyclopædia*; but in that work was given no account of its antiquity or its invention. In the works of Aristotle we read of a kind of kettle used by divers to enable them to remain for some time under water; but the manner in which those kettles were employed is not clearly described. "The oldest information (says Professor Beckmann) which we have of the use of the diving bell in Europe, is that of John Taissier, who was born at Hainault in 1509, had a place at court under Charles V. whom he attended on his voyage to Africa. He relates in what manner he saw at Toledo, in the presence of the emperor and several thousand spectators, two Greeks let themselves down under water, in a large inverted kettle, with a burning light, and rise up again without being wet. It appears that this art was then new to the emperor and the Spaniards, and that the Greeks were caused to make the experiment in order to prove the possibility of it."

When the English, in 1588, dispersed the Spanish fleet, called the Invincible Armada, part of the ships went to the bottom, near the Isle of Mull, on the western coast of Scotland; and some of these, according to the account of the Spanish prisoners, contained great riches. This information excited, from time to time, the avarice of speculators, and gave rise to several attempts to procure part of the lost treasure. In the year 1665, a person was so fortunate as to bring up some cannon, which, however, were not sufficient to

defray the expences. Of these attempts, and the kind of diving bell used in them, the reader will find an account in a work printed at Rotterdam in 1669, and entitled *G. Sinclari Ars nova et magna gravitatis et levitatis*. In the year 1680, William Phipps, a native of America, formed a project for searching and unloading a rich Spanish ship sunk on the coast of Hispaniola; and represented his plan in such a plausible manner, that King Charles II. gave him a ship, and furnished him with every thing necessary for the undertaking. He set sail in the year 1683; but being unsuccessful, returned again in great poverty, though with a firm conviction of the possibility of his scheme. By a subscription promoted chiefly by the Duke of Albemarle, the son of the celebrated Monk, Phipps was enabled, in 1687, to try his fortune once more, having previously engaged to divide the profit according to the twenty shares of which the subscription consisted. At first all his labour proved fruitless; but at last, when his patience was almost entirely exhausted, he was so lucky as to bring up, from the depth of six or seven fathoms, so much treasure that he returned to England with the value of two hundred thousand pounds sterling. Of this sum he himself got about sixteen, others say twenty thousand, and the duke ninety thousand pounds. After he came back, some persons endeavoured to persuade the king to seize both the ship and the cargo, under a pretence that Phipps, when he solicited for his majesty's permission, had not given accurate information respecting the business. But the king answered, with much greatness of mind, that he knew Phipps to be an honest man, and that he and his friends should share the whole among them had he returned with double the value. His majesty even conferred upon him the honour of knighthood, to shew how much he was satisfied with his conduct. We know not the construction of Phipps's apparatus: but of the old figures of a diving-machine, that which approaches nearest to the diving-bell is in a book on fortification by Lorini; who describes a square box bound round with iron, which is furnished with windows, and has a stool affixed to it for the diver. This ingenious contrivance appears, however, to be older than that Italian; at least he does not pretend to be the inventor of it.

In the year 1617, Francis Kessler gave a description of his water-armour, intended also for diving, but which cannot really be used for that purpose. In the year 1671, Witfen taught, in a better manner than any of his predecessors, the construction and use of the diving-bell; but he is much mistaken when he says that it was invented at Amsterdam. In 1679 appeared, for the first time, Borelli's well known work *de motu animalium*; in which he not only described the diving-bell, but also proposed another, the impracticability of which was shewn by James Bernoulli. When Sturm published his *Collegium curiosum* in 1678, he proposed some hints for the improvement of this machine, on which remarks were made in the *Journal des sçavans*. To him succeeded Dr Halley, whose bell is well known.

DODECATEMORY, the 12 houses or parts of the zodiac of the primum mobile. Also the 12 signs of the zodiac are sometimes so called, because they contain each the 12th part of the zodiac.

DOME. See ARCH in this Supplement.

DOMINGO,

Domingo,
Don.

DOMINGO, or ST DOMINGO. See HISPANIOLA, both in *Encycl.* and in this Supplement.

DON MARTIN DE MAYORGA, the name given by the Spaniards to a cluster of islands in the South Sea, discovered on the 27th of February 1781 by Don F. A. Maurelle, a celebrated pilot of that nation.

Those islands are described by him as abounding with tropical fruits and roots, as highly cultivated, and as inhabited by a people considerably polished. The fertility of the land, says he, is such, that its cultivation cannot fail to promise a favourable harvest. Every where are seen an endless number of cocoa-nut trees, beautiful banana trees ranged in lines with the greatest order, and numerous plantations of potatoes, of which he describes some as fifteen feet in length, and of the thickness of a man's thigh. He admired the order with which every thing was disposed. No weeds were suffered to grow between the plants; and their roads were kept in repair with a diligence deserving imitation by the most civilized nations.

Their government appears from his account to be despotic. The sovereign, who is called the *Tubou*, is held in the highest veneration by his subjects, whose lives and properties are at his disposal. Under him there is an order of nobles called *Equis*, who, though they shrink into insignificance in the presence of the *Tubou*, have great authority over the people. These people are said by Maurelle to be of great muscular strength and large stature, the ordinary height of the men being six feet or six feet four inches, while many of them are much taller. It would appear, too, that they delight in gymnastic exercises; for when the *Tubou*, by whom he had been treated with great hospitality, wished to amuse him and his ship's company, he exhibited to them feats of wrestling and boxing, and that as well by the women as by the men.

Though these people put the greatest confidence in the Spaniards, and frequently staid whole nights on board the frigate, they had yet the common inclination of savages to steal. "Every time they came on board (says our author), clothes, iron-work, whatever fell in their way, they considered as lawful prize. They drew out through the port-holes, or the windows, whatever was within their reach. They thieved even to the very chain of the rudder. I made my complaints to the king; he gave me permission to kill whomsoever I should detect in the act; and I was assured he had himself discovered and punished with death the authors of the complained-of theft. Our vigilance was necessarily called into action; we surprised the islanders striving to tear away the new rudder chains; we fired a pistol at them, one of them fell dead on the occasion, and this was an awful lesson for those who were either on board or alongside of the frigate; they said to themselves, or to one another, *chito* (robber) *fama* (death)."

They make of the bark of trees a kind of cloth not unlike that which has been brought from other islands in the South Sea; and our author describes the women as being peculiarly neat both in their dress and in their persons. They had their mantles or loose garments adjusted in neat plaits and folds, and becomingly attached by a knot over the left shoulder. They wore garlands or wreaths on the head, and chaplets of large glass beads round their necks; the hair was pleasingly disposed in tresses, and the whole person perfumed with

an oil of an agreeable odour; above all, the skin was so exquisitely clean, that they would not have suffered the smallest particle of dust to remain upon it a moment.

In this archipelago Don Maurelle found a safe harbour, to which he gave the name of El Refugio; and which he places in South Lat. 18°. 36'. and W. Lon. 177°. 47'. 45". of Greenwich.

DRACÆNA DRACO (see DRACÆNA, *Encycl.*), is a native of Madeira, though it is there becoming scarce. The following account of it is by La Martiniere, naturalist in the last voyage of discovery by La Perouse. "The idea of the *dracœna draco* (says he) given by the shabby specimens cultivated in our hot-houses, is far inferior to that we entertain of it when we have an opportunity of seeing it in its native soil. I met with three in particular, of which the trunk was six or seven feet high, and four and a half, or five in diameter. The principal branches, 12 or 15 in number, and as thick as a man's body, shoot out a little obliquely, dividing themselves generally into two, and now and then into three, to the height of 40 or 50 feet, including the seven feet of the trunk. The leaves are all at the extremity of the branches, where they are placed in alternate order, and form a cluster. This tree presents the most perfect regularity to the eye, and tempts the spectator to think that the most skilful gardener makes it the object of his daily care."

DRAINS. Under this word in the *Encyclopædia* we published Mr Bayley of Hope's method of draining land; and by a letter from the author, we have since learned, that experience, the best guide, has fully proved the usefulness and durability of his *drains*. With a candour, however, worthy of a man who writes not for fame, but for the good of the public, he informs us of a mistake into which he had led us; and requests us to correct it in this Supplement.

"I wish (says he) that, in the Supplement to the *Encyclopædia*, due notice may be taken of a very great error into which I was led in my scheme of making the *main drains*. I conjectured, that where the bottom of the trench was of a hard or solid body, as *clay* or *marl*, it might not be necessary to lay it with bricks or stones; but in this I was quite wrong. By the runs of water, the alternate changes from wet to dry, and the access of air, these hard bottoms have been rendered friable; they have crumbled away, and let in all my drains which were not supported by a bottom laid with brick or stone." For this information we request the author to accept of our thanks, and we are persuaded we may add the thanks of the public.

As the draining of land is a matter of great importance in agriculture, and as the subject has been again brought before us, we imagine that our agricultural readers will be glad to find here the substance of a paper on this subject, for which the author received the silver medal of the *Society* instituted for the encouragement of ARTS, MANUFACTURES, and COMMERCE. That author is Mr JOHN WEDGE of Bickenhill, near Coventry, who is not only a great farmer himself, but had likewise been employed by the Earl of Alesford in the management of several estates. Encouraged by his lordship's liberality, Mr Wedge informs the society, that he had been employed for some years in draining large portions of land, of which part was in the Earl's occupation, and part in his own, as tenant to his lordship.

The

Dracœna,
Drains.

Drains. The principles upon which he proceeded, as well as his mode of procedure, he states in the following terms:

In every country there are large portions of land that, in wet seasons, have always what may be called a *dry surface*, and other portions of land that have always a *moist* or *wet surface*; the former of these admitting all the water which falls upon them to sink freely through their pores to various depths, till falling on clay, or some other unctuous earth, whose pores will not permit it to pass through, it is there held up to a height proportioned to the quantity of water which comes upon it, and the facility with which that water is discharged. Thus, held up to various heights, it serves as a fountain to distribute its water (either by veins of sand, pebbles, or rock), according to the formation of the different under strata on the neighbouring lands, and there forms bogs and other varieties of wet surface, on a basis that will be always found to consist of marl, or clay, or some mixture thereof. The effect of water thus distributed may be divided into two classes. The first class, where the water is thrown out by a body of marl or clay, &c. upon the surface of descending ground, and in the valley (there held up by clay also) forms bogs or swamps. The second class, where the water is held up by marl or clay, as before, having above that marl or clay a stratum of sand, or pebbles, through which the water passes; and above those sands or pebbles another stratum of marl or clay, through the weakest parts of which the water, by a continual pressure from its fountain, forces a passage upwards; and thus, through the weakest parts of the marl or clay, furnishes a continual supply of water on the surface, for the formation or growth of bogs, &c. in proportion as this water is more or less abundantly supplied by its fountain or head, namely, the higher lands, into which rain-water freely passes, as before described. There are also different soils, under different circumstances, which may form a third class of land for draining; such as, strong deep soils, or open light soils, having near the surface a body of marl or clay. In either of these cases, the water which falls on the surface must, for reasons which are self-evident, keep such lands, in rainy seasons, constantly wet and cold; and it should be observed, that a mixture of all the three before-described classes of wet land sometimes occur in one field, by sudden alterations of the under strata, and thereby perplex the operator, by requiring all the different modes of draining in the same field.

If it be admitted that bogs are thus formed and fed, their cure may be effected with certainty. The first class, by cutting through the stratum (be it sand, pebbles, or rock,) that conveys the water to the bog, and carrying off that water by a close drain to some proper place, where the level admits of its discharge. The second class, by sinking a drain to any convenient depth in the upper clay; and then digging or boring with a large auger, at a small distance on one side of this drain, through the remaining part, be it (the upper clay) ever so deep, into the under stratum of sand, pebbles, or rock, through which the water passes; which will then rush up into the drain so made, with a velocity proportioned to the height of the land or fountain whence it is supplied. As this drain advances through the land, holes must be dug or bored, as before, every seven yards, or at such distance as the strength of the

springs may require; and the whole of the water thus brought up by tapping the springs, is carried off by the drain made in the upper clay, which must be a close one, to its proper level, and there discharged.

By both these methods of draining, large tracts of land, under favourable circumstances, may be cured with one drain. The best place for fixing these drains is where the stratum that conveys the water comes nearest to the surface; and the best method of ascertaining that, is to bore or dig in different parts through the different under strata.

The third class may be easily cured by close drains, at such distances and depths as will best carry off the surface-water. It may not be improper to observe, that where the different strata or measures crop out, that is, become gradually more and more shallow in some certain direction (as is often the case, till, one after the other, they all present themselves in succession on the surface of the earth), draining may often be much more easily and better effected by crossing with the drain the different strata or measures where the levels and other circumstances will admit.

Some of the land drained was part of a common, in the parish of Church Bickenhill, in the county of Warwick; part of it was covered with moss and ling, had a peaty surface about six inches deep, and produced little or no grass: in all wet seasons it was filled quite to the surface, and often overflowed, with water. Some of the land was much more unsound, deeper of peat, and covered with moss, in most parts nine inches long; another part was an absolute bog in all seasons.

Having dug or bored with a large auger into several parts of the land, Mr Wedge found peat, gravel, and sand mixed, and a quick-sand almost uniformly. The quick-sand in every part, after getting an inch or two into it, seemed almost as fluid as water. Judging from this, that no materials for a drain could be laid in the quick-sand, but what it would immediately bury, he dug a trench almost to the quick-sand, leaving gravel, &c. of sufficient strength to bear up the materials for a hollow drain; these materials were two sides and a coverer of stone, with a peat-turf on the top to keep out the soil. At every seven yards forward, by the side of this drain, he dug a hole in the quick-sand as deep as it would permit. From these holes the water rose freely into the hollow drain, and was by it discharged at a proper level. It may be proper to remark, that the stone made use of for this drain, and all others here mentioned, was a red sand and rag-stone, which easily split into proper sizes for the purpose, and is very durable; it cost about sixpence per ton getting, exclusive of carriage. The drain thus formed ran on the whole rather freely, and made the land dry for a few yards on each side thereof, but was far from having the effect he improperly expected; for it evidently appears that the drain could only take a very small portion of the water from so large a quick-sand, which it did not penetrate more than two inches; and that it could drain only to its own depth, or, at most, to that depth in the fountain which supplied the quick-sand. His purpose was then defeated; and his motive for mentioning this error cannot, he hopes, be mistaken.

He now did what he says he ought to have done before, that is, examined the different strata to a greater depth, particularly on the bog, and at the upper edges thereof

Drains.

thereof, and found the bog to be what has been described under the first class. He therefore determined to attempt the cure in the manner before prescribed for that class, namely, to cut through the whole of the stratum (in this instance, of quick-sand), through which he found the water pass. This he effected as follows: The summer being dry, and favourable for the purpose, and having previously made his main open drain, he began his main close drain the first week in June 1791, three feet wide, on the declivity near the edge of the great bog. In the first operation he dug through the peat, the hard sand, and gravel, and one spade's graft (about nine inches deep, and seven inches wide) into the quick-sand the whole length of this drain, which was 73 perches, of eight yards to the perch, in length. The drain thus dug ran copiously, not less than 60 gallons per minute. In this state he left it about nine days: the effect of it was rapid, both above the drain and on the bog below. Upon examination, he now found about three inches on the top of the spade's graft, which had been made into the quick-sand perfectly dry. He then dug out these three inches of dry sand, to nearly the whole width of the drain, three feet; and at the same time dug out, as before, another spade's graft from the top of the quick-sand, as near the middle of the drain as possible. This was left to run a few days, as before, and had the same effect, namely, three or four inches more of the top of the quick-sand became dry and hard. The same operation was repeated again and again with the same effect, till the purpose of getting through this quick-sand was completed, so far at least as the level of the main open drain would permit. The stream of water continued increasing during the whole operation; the bog below the drain was quite dry, and the land above perfectly so. The drain which was first made, and continued running for some time during the progress of the main close drain, became gradually dry; and has not, since that drain was finished, discharged one single drop of water. Great care was necessary, in making the main close drain, to keep the stream of water in the middle of it, otherwise the current would have undermined the sides, as it sometimes had done, and caused them to fall in. For this reason it was necessary, when the dry sand was taken from the top of the quick-sand, immediately to take out a spade's graft from the middle thereof, in order to divert the current from the sides.

The main close drain thus made was three feet wide at top, about nine feet deep on the average, and, beveling a little from the top, it was about one foot ten inches wide at the bottom. The stone and other materials were put into this drain in the following manner:

Where the drain went through the quick-sand into the stratum of clay below it, as in most places it did, the bottom, and in some instances the sides, wanted no particular security (A); but where it did not go quite through the quick-sand, which the level of his main open drain in some places would not admit, the bottom of the drain was covered half an inch thick with ling; then peat-turfs, one foot wide and three or four inches thick, were cut in convenient lengths, and placed on

Drains, their edges on each side of the bottom of the drain, forming two sides of a trough of peat; then side stones about eight inches high, and a stone coverer, were put in upon the ling between the peat-turfs; a large peat-turf, near two feet wide and four inches thick, was then cut and firmly placed over the whole: this left in the bottom of the drain an open space, of more than six inches square, for the water to pass. The whole was then completed by filling in the upper part of the drain.

In this way the author drained, for about L. 80, thirty acres of land, which, from being of no value whatever, became worth at least 14 shillings per acre of yearly rent. He likewise hollow-drained nine acres by the method prescribed for the third class of wet land. These drains were made a few yards below that part of each field where the dry and wet land separate, about 22 inches deep, with sides and a coverer of stone, and ling on the top of it, to keep the earth from running in. The length of these drains was 880 yards, and the expence of labour and materials three halfpence per yard. The drains, in wet weather, discharge a large quantity of water; and will, he has no doubt, answer the intended purpose. Thus far relates to land in his own occupation.

Nine acres of the land in the earl of Aylesford's occupation was almost an entire pulp. This bog was of the second class, namely, water passing through a quick-sand, and confined by a stratum of clay below, and another stratum of clay above it. The water thus confined, being pressed by its fountain, and forced up thro' the weakest parts of the clay, had formed a bog of irregular thickness on the surface, in some places six feet deep, in others not more than two. As there is a considerable fall in this land from east to west, he thought it expedient to put two drains into it; and this appears to him to have been necessary, from a consideration that both these drains continue to run in the same proportions as when first opened. The manner in which these drains were executed was, by digging through the different upper strata, and as deep into the clay as the main open drain would admit; then digging or boring through the remaining part of that clay into the quick-sand; at the distance of about six yards in a progressive manner.

The water rising rapidly through these holes into the close drains, has effected a complete cure of this land, every part of which will now bear a horse to gallop upon it. These drains discharge 3660 gallons an hour; which is much less than they did at first, as must be the case in all bogs. This land will be worth twenty shillings per acre. The draining cost twenty-five pounds; and the length of the under-ground drains is eight hundred and fourteen yards.

Mr Wedge had just finished (January 1792) draining another piece of land, about forty-three acres. As this was intended to answer two purposes, one, to drain the land, the other, to give an additional supply of water to a mill-pool, and as a circumstance arose in the execution of the work which frequently happens in draining land, namely, a sudden alteration in the position

(A) He will probably find in time that he was under the same mistake with Mr Bayley, and we hope that with Mr Bayley's candour he will acknowledge it.

Drains,
Drosera.

sition of the under strata—a description thereof will not, we hope, be thought tedious. This draining was begun at the level of a mill-pool, and continued, without any great difficulty, to the distance of about thirty-two chains, in the manner before described as a cure for the second class of boggy land: but at or near that place the under strata altered their position; the quicksand which conveyed the water now became of twice its former thickness; and the clay, which had hitherto been above that quicksand, for some distance disappeared. From the quicksand thus becoming so much deeper, he could not, with the level of the mill-pool, cut through it; nor indeed, from the wetness of the season, would such an operation have been proper. He therefore continued a shallow drain to some distance, making side-holes into the quicksand, which ran freely; but as this could not cure the whole of the bog below, he branched out another drain (which was made by the method described for curing the second class of wet or boggy land), by sinking a close drain through the upper strata into the upper clay, and then, at a small distance on one side of this close drain, boring a hole with an auger through the remaining part of that clay into the quicksand; and at every eight yards, as this close drain advanced, still boring other holes, in the manner before described: through many of these holes the water rushed with great rapidity. The water discharged by these drains into the mill-pool is 168 gallons per minute, or 3780 hogheads in a day; which is after the rate of 1,379,700 hogheads in a year.

About six acres of this land were always found; about twelve acres on the north side were an absolute pulp, and the remaining twenty six acres very unbound. The whole is now sound, and will, when cultivated, be worth sixteen shillings per acre. This land would have been drained at a much less expence into the main open drain; but then the water, which was much wanted for the mill, would have been lost. These close drains are in length 1452 yards, and cost L. 100, of which about L. 30 ought to be charged to the mill.

Important as this subject is, we must not enlarge this article, or we should make large extracts from Dr Anderson's *Practical Treatise on Draining Bogs and Swampy Grounds*, lately published. It is proper, however, to inform the public, that the author puts in his claim for being the first discoverer of that mode of draining for which Mr Elkington has obtained from Parliament a premium of L. 1000; and the reader who shall turn to the article DRAINS in the Encyclopædia, will perceive that his claim is well-founded.

DROSSERA ANGLICANA, or the SUNDEW (see DROSSERA, *Encycl.*), is a very minute villous plant, usually growing entangled with moss on peat bogs; the leaves are curiously fringed with numerous strong reddish hairs, terminated by small pellucid globules of viscid liquor, which occasion, by the reflection of the sun, that peculiar lustre from which its name is derived. It is in these hairs that these essential properties of the plant reside; for if a small insect should fix itself on one of the leaves, these hairs immediately begin to close, one by one, till the insect is wholly environed by them, and then the leaf in which it is imprisoned gradually bends inwards, so as to reach the base: in this state the insect is killed by the operation of the acrimonious juice exuding from the ends of the hairs. Rothius

(as quoted by Withering, in his Arrangement of British Plants,) mentions the effects of this singular plant, occasioned by the irritation of an ant, which he placed on the centre of one of the leaves with a pair of pincers. The ant, in endeavouring to escape, was held fast by the viscid juice of the smaller hairs till the large ones, together with the edges of the leaf, closed in and imprisoned it. The ant died in fifteen minutes; but he observes, that the effects followed sooner or later, in different experiments, according to the state of the weather. Dr Withering has published a similar account of the sensitive properties of the sundew, which was communicated to him by two of his botanical friends, and which he has made very entertaining and interesting. The same thing is confirmed by a writer in the Monthly Magazine for August 1797; who says, that whenever he made experiments on the drosera with ants and other diminutive insects, he commonly found them perish in a shorter time than fifteen minutes. His experiments were made on the drosera rotundifolia. Rothius, however, observes, that the longifolia produces the same effects, but with greater rapidity. In concluding his account, Dr Withering suggests this enquiry, "Whether this destruction of insects be not necessary to the welfare of the plant?" And it is surely worth some botanist's while to take some pains to answer the question.

DRUGS (see *Encycl.*) are so commonly counterfeited, or at least adulterated, that, in London, the royal college of physicians, it is well known, has long ago appointed a court of examiners to investigate the goodness of drugs and medicines in the different chemists and apothecaries shops. The counterfeit, however, is made up with such dexterity, that not only the merchant and drug-broker, but even the man of skill, is sometimes deceived; and indeed nothing can detect this imposition but a practical knowledge of chemistry. We therefore recommend it to every father of a family to study our Supplementary article CHEMISTRY with this view, if with no other; for whatever be the faults of that article, we have lost much labour if it be not sufficiently perspicuous to enable every man, not an absolute stranger to physical science in all its branches, to detect the common impostures of drug-sellers.

DUFTER, in Bengal, an office or department.

DUFTER Cana, the place where the office is kept.

DWARFING OF VEGETABLES, an art invented by the Chinese, to which the attention of Sir George Staunton was attracted on the following occasion:

When the embassy was at Chusan (See CHUSAN in this Supplement), the gentlemen who went on shore were introduced to the governor in his hall of audience, where on several tables were placed, in frames filled with earth, dwarf pines, oaks, and orange trees, bearing fruit. None of them exceeded in height two feet. Some of those dwarfs bore all the marks of decay from age: and upon the surface of the soil were interspersed small heaps of stones, which, in proportion to the adjoining dwarfs, might be termed rocks. These were honey-combed and moss-grown, as if untouched for ages, which served to maintain the illusion, and to give an antique appearance to the whole. This kind of stunted vegetation seemed to be much relished by the curious in China; and specimens of it were to be found in every considerable dwelling. To produce them formed a part of the gardener's skill, and was an art invented

Drugs
||
Dwarfing.

Dwarfing. in that country. Beside the mere merit of overcoming a difficulty, it had that of introducing vegetables into common apartments, from which their natural size must otherwise have excluded them.

The general method of obtaining vegetable dwarfs is said to be the following: A quantity of clay or mould is applied to the upper part of the trunk of a tree, from which a dwarf is intended to be taken, and close to its division into branches. The mould is to be confined to the spot by coarse hempen or cotton cloth, and to be carefully kept moist by water. In consequence of this application, continued sometimes above a twelvemonth, small tender fibres shoot down like roots from the wood into the mould. The part of the trunk emitting those new fibres, together with the branch rising immediately above it, is then to be carefully separated from the rest of the tree, and planted in new earth, in which the fibres become new roots, while the former branch is now the stem of the vegetable thus transformed in some measure. This operation does not destroy or alter the productive faculty which those parts enjoyed before their separation from their parent root. That which, while a branch of the original tree, bore flowers and fruit, continues to produce the same, though no longer supported upon any stock. The terminal buds of such branches of trees as are meant to become dwarfs are torn off; which circumstance prevents the further elongation of those branches, and forces other buds and branchlets from the sides. These branchlets are bent by wires to

whatever form the operator wishes: and when the appearance of age and decay is meant to be given to a dwarf tree, it is repeatedly smeared with treacle or molasses, which attracts multitudes of ants, who, in pursuit of those sweet juices, attack the bark, and, by a gradual corrosion of it, produce the desired effect. These different processes are sometimes attempted to be kept secret by the gardeners, and they vary designedly in the mode of carrying them on; but the principle on which they are founded is sufficiently apparent from what is related here; and the contrivance argues ingenuity and perseverance, rather than the practice does true taste, which consists in assisting Nature in its most favourite works—not in counteracting its operations or distorting its productions.

DYEING is an art into which, since the article in the Encyclopædia was published, improvements have been introduced of such importance, that it would be unpardonable not to notice them in this Supplement. They ought to be noticed under the present title; but, for reasons assigned at the time, we were under the necessity of postponing them, in the first edition, to the title *Vegetable, Animal, and Dyeing SUBSTANCES*. We might now restore the article DYEING to its proper place; but though we confidently announce this as an improved edition, we doubt whether we can, in justice to the purchasers of the first edition, alter its arrangement. We therefore still refer the reader to the article *Dyeing SUBSTANCES*.

D Y N A M I C S.

¹ **Definition.** THIS name marks that department of physico-mathematical science which contains the abstract doctrine of MOVING FORCES; that is, whatever necessarily results from the relations of our ideas of motion, and of the immediate causes of its production and changes.

² **Object of dynamics** is that change of a thing which we call its motion. All changes of motion are considered by us as the indications, the characteristics, and the measures of changing causes. This is a physical law of human thought, and therefore a principle to which we may refer, and from which we must derive all our knowledge of those causes. When we appeal to our own thoughts or feelings, we do not find in ourselves any disposition to refer mere existence to any cause, although the beginning of existence certainly produces this reference in an instant. Had we always observed the universe in motion, it does not appear that we should have ascribed it to a cause, till the observation of relative rest, or something leading to it, had enabled us to separate, by abstraction, the notion of matter from that of motion. We might then perceive, that rest is not incompatible with matter; and we might even observe, by means of relative motions, that absolute rest might be produced by the concurrence of equal and opposite motions. But all this requires reflection and reasoning; whereas we are now speaking of the first suggestions of our minds.

³ We cannot have any notion of motion *in abstracto*, without considering it as a state or condition of existence, which would remain, if not changed by some cause. It is from changes alone, therefore, that we infer any agency in nature; and it is in these that we are to find all that we know of their causes.

When we look around us, we cannot but observe ⁴ that the motions of bodies have, in most cases, if not relation, always, some relation to the situation, the distance, and the discriminating qualities of other bodies. The motions of the moon have a palpable relation to the earth; the motions of the tides have as evident a relation to the moon; the motions of a piece of iron have a palpable dependence on a magnet. The vicinity of the one seems to be the occasion, at least, of the motions of the other. The causes of these motions have an evident connection with or dependence on the other body. We are even disposed to imagine, that they are inherent in that body, and that it possesses certain qualities which are the causes of those modifications of motion in other bodies. These serve to distinguish some bodies from others, and may therefore be called PROPERTIES; and, since the condition of other bodies so evidently depends on them, these properties express very interesting relations of bodies, and are chiefly attended to in the enumeration of the circumstances which ascertain what we call the *nature* of any thing. We do not mean to say that these inferences are always just; nay, we know that many of them are ill-founded: but they are real, and they serve abundantly for informing us what we may expect from any proposed situation of things. It is enough for us to know, that when a piece of iron is so and so situated in relation to a magnet, it will move in a certain manner.

This mutual relation of bodies is differently considered, according to the interest that we chance to take in the phenomenon. The cause of the approach of the iron to a magnet is generally ascribed to the magnet, which

which is said to attract the iron, because we commonly employ the magnet in order that these motions may take place. The similar approach of a stone to the earth is ascribed to the stone, and we say that it tends to the earth. In all probability, the procedure of nature is the same in both; for they are observed, in every instance, to be mutual between the related bodies. As iron approaches a magnet, so the magnet approaches the iron. The same thing is observed in the motions of electrified bodies; also in the case of the stone and the earth. Therefore the cause of the motions may be conceived as inherent in either, or in both.

Force and Action are figurative terms when used in mechanism;

The qualities thus inherent in bodies, constituting their mechanical relations, have been called the MECHANICAL AFFECTIONS OF MATTER. But they are more commonly named POWERS or FORCES; and the event which indicates their presence, is considered as the effect and mark of their agency. The magnet is said to ACT on the iron, the earth is said to ACT on the stone, and the iron and the stone are said to ACT on the magnet and on the earth.

All this is figurative or metaphorical language. All languages have begun with social union, and have improved along with it. The first collections of words expressed the most familiar and the most interesting notions. In the process of social improvement, the number of words did not increase in the same proportion with the notions that became interesting and familiar in their turn: for it often happened that relations of certain ideas so much resembled the relations of certain other ideas, that the word expressing one of them served very well for expressing the other; because the dissimilar circumstances of the two cases prevented all chance of mistake. Thus we are said to *surmount* a difficulty without attaching to the word the notion of *getting over* a steep hill. Languages are thus filled with figurative expressions.

POWER, FORCE, and ACTION, are words which must have appeared in the language of the most simple people; because the notions of personal ability, strength, and exertion, are at once the most familiar and the most interesting that can have a place in the human mind. These terms, when used in their pure, primitive sense, express the notions of the power, force, and action of a sentient, active, being. Such a being only is an agent. The exertion of his power or force is (exclusively) action: But the relation of cause and effect so much resembles in its results the relation between this force and the work performed, that the same term may be very intelligibly employed for both. Perhaps the only case of pure unfigurative action is that of the mind on the body. But as this is always with the design of producing some change on external bodies, we think only of them; the instrument or tool is overlooked, and we say that we act on the external body. Our *real* action therefore is but the first movement in a long train of successive events, and is but the remote cause of the interesting event. The resemblance to such actions is very strong indeed in many cases of mechanical phenomena. A man throws a ball by the motion of his arm. A spring impels a ball in the same manner by unbending. These two events resemble each other in every circumstance but the action of the mind on the corporeal organ—the rest of it is a train of pure mechanism. In general, because the ultimate results of the mutual influence of bodies on each other greatly

resemble the ultimate results of our actions on bodies, we have not invented appropriated terms, but have contented ourselves with those already employed for expressing our own actions, the exertions of our own powers or forces. The relation of physical cause and effect is expressed metaphorically in the words which belong properly to the relation of agent and action. This has been attended by the usual consequences of poverty of language, namely, ambiguity, and sometimes mistake, both in our reflections (which are generally carried on by mental discourse), our reasonings, and our conclusions. It is necessary to be on our guard against such mistakes; for they frequently amount to the confounding of things totally different. Many philosophers of great reputation, on no better foundation than this metaphorical language, have confounded the relations of activity and of causation, and even denied that there is any difference; and they have affirmed, that there is the same invariable relation between the determinations of the will and the inducements that prompt them, as there is between any physical power and its effect. Others have maintained, that the first mover in the mechanical operations, and indeed through the whole train of any complicated event, is a percipient and intending principle in the same manner as in our actions. According to these philosophers, a particle of gravitating matter perceives its relation to every other particle in the universe, and determines its own motion according to fixed laws, in exact conformity to its situation. But the language, and even the actions of all men, shew that they have a notion of the relation of an agent to the action, easily distinguishable (because all distinguish it) from the relation between the physical cause and its effect. The proofs of this fact have been adduced in other parts of the Encyclopædia Britannica, as, for example, in the article PHILOSOPHY, n^o 42. and in this Supplement in the article ACTION.

These remarks are not made in this place for any philological purpose, such as the mere improvement of language; but because this metaphorical language has affected the doctrines of mechanical philosophy, and has produced a dispute about some of its first principles; and because we find that the only way to decide this dispute: is to avoid, most scrupulously, all metaphorical language, though at the expence of much circumlocution.

When we speak of powers or forces as residing in a body, and the effect as produced by their exertion, the body, considered as possessing the power, is said to ACT on the other. A magnet is said to act on a piece of iron; a billiard ball in motion is said to act on one that is hit by it: but if we attempt to fix our attention on this action, as distinct both from the agent and the thing acted on, we find no object of contemplation—the exertion or procedure of nature in producing the effect does not come under our view. When we *speak* of the action as distinct from the agent, we find that it is not the action, properly speaking, but the act, that we speak of. In like manner, the action of a mechanical power can be conceived only in the effect produced.

A man is not said to act unless he produces some effect. Thought is the act of the thinking principle; motion of the limb is the act of the mind on it. In mechanics, also, there is action only in so far as there is mechanical effect produced. I must act violently in order

But the analogy is not in the force, but in the effect.

Directions for the safe employment of this analogy.

Action implies a change; and mere motion is not action.

order to begin motion on a slide : I must exert force, and this force exerted produces motion. I conceive the production of motion, in all cases, as the exertion of force ; but it requires no exertion to continue the motion along the slide ; I am conscious of none, therefore I ought to infer that no force is necessary for the continuation of any motion. The continuation of motion is not the production of any new effect, but the permanency of an effect already produced. We indeed consider motion as the effect of an action ; but there would be no effect if the body were not moving. Motion is not the action, but the effect of the action.

8
Pressure, im-
pulsion.

Mechanical actions have been usually classed under two heads : they are either PRESSURES or IMPULSIONS. They are generally considered as of different kinds ; the exertions of different powers. PRESSURE is supposed to differ essentially from IMPULSE.

Instead of attempting to define, or describe, these two kinds of forces and actions, we shall just mention some instances. This will give us all the knowledge of their distinctions that we can acquire.

Examples
of pressure.

When a ball lies on a table, and I press it gently on one side, it moves toward the other side of the table. If I follow it with my finger, continuing my pressure, it accelerates continually in its motion. In like manner, when I press on the handle of a common kitchen jack, the fly begins to move. If I continue to urge or press round the handle, the fly accelerates continually, and may be brought into a state of very rapid motion. These motions are the effects of genuine pressure. The ball would be urged along the table in the same manner, and with a motion continually accelerated, by the unbending of a spring. Also, a spring coiled up round the axis of the handle of the jack would, by uncoiling itself, urge round the fly with a motion accelerating in the same way. The more I reflect on the pressure of my finger on the ball, and compare it with the effect of the spring on it, the more clearly do I see the perfect similarity ; and I call these influences, exertions, or actions, by one name, PRESSURE, taken from the most familiar instance of them.

Again, the very same motion may be produced in the ball or fly, by pulling the ball or the machine by means of a thread, to which a weight is suspended. As both are motions accelerated in the same manner, I call the influence or action of the thread on the ball or machine by the same name PRESSURE, and WEIGHT is considered as a pressing power. Indeed I feel the same compression from the real pressure of a man on my shoulders that I would feel from a load laid on them. But the weight in our example is acting by the intervention of the thread. By its pressure, it is pulling at that part of the thread to which it is fastened ; this part is pulling at the next by means of the force of cohesion ; and this pulls at a third, and so on, till the most remote pulls at the ball or the machine. Thus may elasticity, weight, cohesion, and other forces, perform the office of a genuine power ; and since their result is always a motion beginning from nothing, and accelerating by perceptible degrees to any velocity, this resemblance makes us call them by one familiar name.

But farther, I see that if the thread be cut, the weight will fall with an accelerated motion, which I will increase to any degree, if the fall be great enough. I ascribe this also to a pressing power acting on the weight. Nay, after a very little refinement, I consider

this power as the cause of the body's weight ; which word is but a distinguishing name for this particular instance of pressing power. Gravitation is therefore added to the list of pressures ; and, for similar reasons, the attractions and repulsions of magnets or electric bodies may be added to the list ; for they produce actual compressions of bodies placed between them, and they produce motions gradually accelerated, precisely as gravitation does. Therefore all these powers may be distinguished by this descriptive name *pressures*, which, in strict language, belongs to one of them only.

Several writers, however, subdivide this great class into pressures and solicitations. Gravity is a solicitation *ab extra*, by which a body is urged downward. In like manner, the forces of magnetism and electricity, and a vast variety of other attractions and repulsions, are called *solicitations*. We see little use for this distinction, and the term is too like an affection of mind.

9
Examples
of impul-
sion.

IMPULSION is exhibited when a ball in motion puts another ball into motion by hitting, or (to speak metaphorically) by striking it. The appearances here are very different. The body that is struck acquires, in the instant of impulse, a sensible quantity of motion, and sometimes a very rapid motion. This motion is neither accelerated nor retarded after the stroke, unless it be affected by some other force. It is also remarked, that the rapidity of the motion depends, *inter alia*, on the previous velocity of the striking body. For instance, if a clay ball, moving with any velocity, strike another equal ball which is at rest, the struck ball moves with half the velocity of the other. And it is farther remarkable, that the striking body always loses as much motion as the struck body gains. This universal and remarkable fact seems to have given rise to a confused or indistinct notion of a sort of transference of motion from one body to another. The phraseology in general use on this subject expresses this in the most precise terms. The one ball is not said to cause or produce motion in the other, but to *communicate* motion to it ; and the whole phenomenon is called the *communication of motion*. We call this an *indistinct* notion ; for surely no one will say that he has any clear conception of it. We can form the most distinct notion of the communication of heat, or of the cause of heat ; of the communication of saltiness, sweetness, and a thousand other things ; but we cannot conceive how part of that identical motion which was formerly in A, is now infused into B, being given up by A. It is in our attempt to form this notion that we find that motion is not a thing, not a substance which can exist independently, and is susceptible of actual transference. It appears in this case to be a state, or condition, or mode of existence, of which bodies are susceptible, which is producible, or (to speak without metaphor) causable, in bodies, and which is the effect and *characteristic* of certain natural qualities, properties, or powers. We are anxious to have our readers impressed with clear and precise notions on this subject, being confident that such, and only such, will carry them through some intricate paths of mechanical and philosophical research.

10
Inherent
force is the
distinctive
character of
impulsion,

The remarkable circumstance in this phenomenon is, that a rapid motion, which requires for the effecting it the action of a pressing power, continued for a sensible and frequently a long time, seems to be effected in an instant by impulsion. This has tended much to support the notion of the actual transference of something formerly

formerly possessed exclusively by the striking body, inhering in it, but separable, and now transfused, into the body stricken. And now room is found for the employment of metaphor, both in thought and language. The *striking* body affects the body which it thus impels: It therefore possesses the *power* of impulsion, that is, of *communicating* motion. It possesses it only while it is in motion. This *power*, therefore, is the efficient distinguishing cause of its motion, and its only office must be the continuation of this motion. It is therefore called the *INHERENT FORCE*, the force inherent in a moving body, *VIS INSITA corpori moto*. This force is transfused into the body impelled; and therefore the transference is instantaneous, and the impelled body continues its motion till it is changed by some other action. All this is at first sight very plausible; but a scrupulous attention to those feelings which have given rise to this metaphorical conception, should have produced very different notions. I am conscious of exertion in order to begin motion on a slide; but if the ice be very smooth, I am conscious of no exertion in order to slide along. My power is felt only while I am conscious of exerting it: Therefore I have no primitive feeling or notion of power while I am sliding along. I am certain that no exertion of power is necessary here. Nay, I find that I cannot think of my moving forward without effort otherwise than as a certain mode of my existence. Yet we imagine that the partisans of this opinion did really deduce it in some shape from their feelings. We must continue the *exertion* of walking in order to walk on; our power of walking must be continually exerted, otherwise we shall stop. But this is a very imperfect, incomplete, and careless observation. Walking is much more than mere continuance in progressive motion. It is a continually repeated lifting our body up a small height, and allowing it to come down again. This renewed ascent requires repeated exertion.

We have other observations of importance yet to make on this force of moving bodies, but this is not the most proper occasion. Mean while we must remark, that the instantaneous production of rapid motion by impulse has induced the first mechanicians of Europe to maintain, that the power or force of impulse is unsusceptible of any comparison with a pressing power. They have asserted, that impulse is infinitely great when compared with pressure; not recollecting that they held them to be things totally disparate, that have no proportion more than weight and sweetness. But these gentlemen are perpetually enticed away from their creed by the similarity of the ultimate results of pressure and impulse. No person can find any difference between the motion of two balls moving equally swift, in the same direction, one of which is descending by gravity and the other has derived its motion from a blow. This struggle of the mind to maintain its faith, and yet accommodate its doctrines to what we see, has occasioned some other curious forms of expression. Pressure is considered as an *effort* to produce motion. When a ball lies on a table, its weight, which they call a *power*, continually and repeated *endeavours* (mark the metaphorical word and thought) to move the ball downward. But these efforts are ineffectual. They say that this ineffectual power is *dead*, and call it a *VIS MORTUA*; but the force of impulsion is called a *VIS VIVA*, a living force. But this is very whimsical and very inaccurate. If the impelling ball falls perpendicularly on the other

lying on the table, it will produce no motion any more than gravity will; and if the table be annihilated, gravity becomes a *vis viva*.

We must now add, that in order to prove that impulse is infinitely greater than pressure, these mechanicians turn our attention to many familiar facts which plead strongly in their favour. A carpenter will drive a nail into a board with a very moderate blow of his hammer. This will require a pressure which seems many hundred times greater than the impelling effort of the carpenter. A very moderate blow will shiver into pieces a diamond which would carry the weight of a mountain. Seeing this prodigious superiority in the impulse, how shall they account for the production of motion by means of pressure? for this motion of the hammer might have been acquired by its falling from a height; nay, it is actually acquired by means of the continued pressure of the carpenter's arm. They consider it as the aggregate of an infinity of succeeding pressures in every instant of its continuance; so that the insignificant smallness of each effort is compensated by their inconceivable number.

On the whole, we do not think that there is clear evidence that there are two kinds of mechanical force essentially different in their nature. It is virtually given up by those who say that impulse is infinitely greater than pressure. Nor is there any considerable advantage to be obtained by arranging the phenomenon under those two heads. We may perhaps find some method of explaining satisfactorily the remarkable difference that is really observed in the two modes of producing motion; namely, the gradual production of motion by acknowledged pressure, and the instantaneous production of it by impulse. Indeed, we should not have taken up so much of our reader's attention with this subject, had it not been for some inferences that have been made from these premises, which meet us in our very entry on the consideration of first principles, and that are of extensive influence on the whole science of mechanical philosophy, and, indeed, on the whole study of nature.

Mechanicians are greatly divided in their opinion about the nature of the sole moving force in Nature. Those whom we are now speaking of, seem to think that all motion is produced by pressure: For when they consider impulse as equivalent to the aggregate of an infinity of repeated pressures, they undoubtedly suppose any pressure, however insignificant, as a moving force. But there is a party, both numerous and respectable, who maintain that impulsion is the sole cause of motion. We see bodies in motion, say they, and we see them impel others; and we see that this production of motion is regulated by such laws, that there is but one absolute quantity of motion in the universe which remains unalterably the same. It must therefore be transfused in the acts of collision. We also see, with clear evidence, in some cases, that motion can produce pressure. Euler adduces some very whimsical and complicated cases, in which an action, precisely similar to pressure, may be produced by motion. Thus, two balls connected by a thread, may be so struck that they shall move forward, and at the same time wheel round. In this case the connecting thread will be stretched between them. Now, say the philosophers, since we see motion, and see that pressure may be produced by motion, it is preposterous to imagine that it is any thing else than

Arguments in distinct and inconclusive.

No difference between pressure and impulsion.

Is impulsion the sole cause of motion?

11 And said to be infinitely greater than pressure.

a result of certain motions; and it is the business of a philosopher to inquire and discover what motions produce the pressures that we observe.

They then proceed to account for those pressing powers, or solicitations to motion, which we observe in the acceleration of falling bodies, the attractions of magnetism and electricity, and many other phenomena of this kind, where bodies are put in motion by the vicinity of other bodies, or (in the popular language) by the action of other bodies at a distance. To say that a magnet cannot act on a piece of remote iron, is to say that it can act *where* it is not; which is as absurd as to say, that it can act *when* it is not. *Nihil movetur, says Euler, nisi a contiguo et moto.*

The bulk of these philosophers are not very anxious about the way in which these motions are produced, nor do they fall upon such ingenious methods of producing pressure as the one already mentioned, which was adduced by Euler. The piece of iron, say they, is put in motion when brought into the neighbourhood of a magnet, because there is a stream of fluid issuing from one pole of the magnet, which circles round the magnet, and enters at the other pole: This stream impels the iron, and arranges it in certain determined positions, just as a stream of water would arrange the flote grafs. In the same manner, there is a stream of fluid continually moving towards the centre of the earth, which impels all bodies in lines perpendicular to the surface; and so on with regard to other like phenomena. These motions are thus reduced to very simple cases by impulsion.

It is unnecessary to refute this doctrine at present; it is enough that it is contrary to all the dictates of common sense. To suppose an agent that we do not see, and for whose existence we have not the smallest argument; with equal propriety we might suppose ministering spirits, or any thing that we please.

Other philosophers are so dissatisfied with this notion of the production of pressure, that they, on the other hand, affirm that pressure is the only moving force in nature; not according to the popular notion of pressure, by the mutual contact of solid bodies, but that kind of pressure which has been called *solicitation*; such as the power of gravity. They affirm, that there is no such thing as contact on instantaneous communication of motion by real collision. They say (and they prove it by very convincing facts (see OPTICS, n^o 63—68. *Encycl.*), that the particles of solid bodies exert very strong repulsions to a small distance; and therefore, when they are brought by motion sufficiently near to another body, they repel it, and are equally repelled by it. Thus is motion produced in the other body, and their own motion is diminished. And they then shew, by a scrupulous consideration of the state of the bodies while the one is advancing and the other retiring, in what manner the two bodies attain a common velocity, so that the quantity of motion before collision remains unchanged, the one body gaining as much as the other loses. They also shew cases of such mutual action between bodies, where it is evident that they have never come into contact; and yet the result has been precisely similar to those cases where the motion appeared to be changed in an instant. Therefore they conclude, that there is no such thing as instantaneous communication, or transfusion of motion, by contact in collision or impulse. The reason why previous motion of the impelling body

is necessary, is not that it may have a *vis insita corpori moto*, a force inherent in it *by its being in motion*, but that it may continue to follow the impelled and retiring body, and exert on it a force inherent in itself, whether in motion or at rest.—According to these philosophers, therefore, all moving forces are of that kind which has been named *solicitation*; such as gravity. We shall know it afterwards by the more familiar and descriptive name of ACCELERATING or RETARDING force.

The exertions of mechanical forces are differently termed, according to the reference that we make to the result. If, in boxing or wrestling, I strike, or endeavour to throw my antagonist, I am said to ACT; but if I only parry his blows, or prevent him from throwing me, I am said to RESIST. This distinction is applied to the exertions of mechanical powers. When one body A changes the motion of another B, we may consider the change in the motion of B either as the indication and measure of A's power of producing motion, or as the indication and measure of A's resistance to the being brought to rest, or having its motion any how changed. The distinction is not in the thing itself, but only in the reference that we are disposed, by other considerations, to make of its effect. They may be distinguished in the following manner: If a change of motion follow when one of the powers ceases to be exerted, that power is conceived as having resisted. The whole language on this subject is metaphorical. Resistance, effort, endeavour, &c. are words which cannot be employed in mechanical discussions without figure, because they all express notions which relate to sentient beings; and the unguarded indulgence of this figurative language has so much affected the imagination of philosophers, that many have almost animated all matter. Perhaps the word REACTION, introduced (we think) by Newton, is the best term for expressing that mutual force which is perceived in all the operations of nature that we have investigated with success. As the magnet attracts iron, and in so doing is said to act on it; so the iron attracts the magnet, and may be said to react on it.

With respect to the difficulty that has been objected to the opinion of those who maintain that all the mechanical phenomena are produced by the agency of attracting or repelling forces; namely, that this supposes the bodies to act on each other at a distance, however small those distances may be, which is thought to be absurd, we may observe, that we may ascribe the mutual approaches or recesses to tendencies to or from each other. What we call *the attraction of the magnet* may be considered as a tendency of the iron to the magnet, somewhat similar to the gravitation of a stone toward the earth. We surely (at least the unlearned) can and do conceive the iron to be affected by the magnet, *without thinking* of any intermedium. The thing is not therefore inconceivable; which is all that we know about absurdity: and we do not know any thing about the nature or essence of matter which renders this tendency to the magnet impossible. That we do not see intuitively any reason why the iron should approach the magnet, must be granted; but this is not enough to entitle us to say, that such a thing is impossible or inconsistent with the nature of matter. It appears, therefore, to be very hasty and unwarrantable, to suppose the impulse of an invisible fluid, of which we know nothing, and of the existence of which we have no proof. Nay,

How does it produce pressure?

Incompatible with the rules of philosophizing.

Others maintain that pressure is the sole moving force.

14
Action, Resistance, Reaction.

15
We need not suppose action at a distance. Tendency.

if

if it be true that bodies do not come into contact, even when one ball hits another, and drives it before it, this invisible fluid will not solve the difficulty; because the same difficulty occurs in the action of any particle of the fluid on the body. We are obliged to say, that the production of motion without any *observed* contact, is a much more familiar phenomenon than the production of motion by impulsion. More motion has been produced in this way by the gravitation of a small stream of water, running ever since the creation, than by all the impulses in the world twice told. We do not mean by this to say, that the giving to this observed mutual relation between iron and a loadstone the name tendency makes it less absurd, than when we say that the loadstone attracts the iron; it only makes it more conceivable: It suggests a very familiar analogy; but both are equally figurative expressions; at least as the word tendency is used at present. In the language of ancient Rome, there was no metaphor when Virgil's hero said, *Tendimus in Latium. Tendere versus solem* means, in plain Latin, to *approach the sun*. The safe way of conceiving the whole is to say, that the condition of the iron depends on the vicinity of the magnet.

When the exertions of a mechanical power are observed to be always directed toward a body, that body is said to attract; but when the other body always moves off from it, it is said to repel. These also are metaphorical expressions. I attract a boat when I pull it toward me by a rope; this is purely ATTRACTION: and it is pure, unfigurative REPULSION, when I push any body from me. The same words are applied to the mechanical phenomena, merely because they resemble the results of real attraction or repulsion. We must be much on our guard to avoid metaphor in our conceptions, and never allow these words to suggest to our mind any opinion about the *manner* in which the mechanical forces produce their effects. It is plain, that if the opinion of those who maintain the existence and action of the above-mentioned invisible fluid be just, there is nothing like attraction or repulsion in the universe. We must always recur to the simple phenomenon, the motion to or from the attraction or repelling body; for this is all we see, and generally all that we know.

We conceive one man to have twice the strength of another man, when we see that he can withstand the united effort of two others. Thus animal force is conceived as a quantity, made up of, and measured by, its own parts. But we doubt exceedingly whether this be an accurate conception. We have not a distinct notion of one strain added to another; though we have of their being joined or combined. We want words to express the difference of these two notions in our own minds; but we imagine that others perceive the same difference. We conceive clearly the addition of two lines or of two minutes; we can conceive them apart, and perceive their boundaries, common to both, where one ends and the other begins. We cannot conceive thus of two forces combined; yet we cannot say, that two equal forces are *not* double of one of them. We measure them by the effects which they are known to produce. Yet there are not wanting many cases where the action of two men, equally strong, does not produce a double motion.

In like manner, we conceive all mechanical forces as measurable by their effects; and thus they are made

the subjects of mathematical discussion. We talk of the proportions of gravity, magnetism, electricity, &c.; nay, we talk of the proportion of gravity to magnetism:—Yet these, considered in themselves, are disparate, and do not admit of any proportion; but they produce effects, some of which are measurable, and whose assumed measures are susceptible of comparison, being quantities of the same kind. Thus, one of the effects of gravity is the acceleration of motion in a falling body: magnetism will also accelerate the motion of a piece of iron; these two accelerations are comparable. But we cannot compare magnetism with heat; because we do not know any measurable effects of magnetism that are of the same kind with any effects of heat.

When we say, that the gravitation of the moon is the 3600th part of the gravitation at the sea-shore, we mean that the fall of a stone in a second is 3600 times greater than the fall of the moon in the same time. But we also mean (and this expresses the proportion of the *tendency* of gravitation more purely), that if a stone, when hung on a spring steelyard, draw out the rod of the steelyard to the mark 3600, the same stone, taken up to the distance of the moon, will draw it out no further than the mark 1. We also mean, that if the stone at the sea-shore draw out the rod to any mark, it will require 3600 such stones to draw it out to that mark, when the trial is made at the distance of the moon. It is not, therefore, in consequence of any immediate perception of the proportion of the gravitation at the moon to that at the surface of the earth that we make such an assertion; but these motions, which we consider as its effects in these situations, being magnitudes of the same kind, are susceptible of comparison, and have a proportion which can be ascertained by observation. It is these proportions that we contemplate; although we speak of the proportions of the unseen causes, the forces, or endeavours to descend. It will be of material service to the reader to peruse the judicious and acute dissertation on *quantity* in the 45th volume of the Philosophical Transactions; or he may study the article QUANTITY in the *Encyclopædia*, where, we trust, he will see clearly how force, velocity, density, and many other magnitudes of very frequent occurrence in mechanical philosophy, may be made the subjects of mathematical discussion, by means of some of those proper quantities, measurable by their own parts, which are to be assumed as their measures. Pressures are measurable only by pressures. When we consider them as moving powers, we should be able to measure them by any moving powers, otherwise we cannot compare them; therefore it is not as pressures that we then measure them. This observation is momentous.

One circumstance must be carefully attended to. That those assumed measures may be accurate, they must be invariably connected with the magnitudes which they are employed to measure, and so connected, that the degrees of the one must change in the same manner with the degrees of the other. This is evident, and is granted by all. But we must also *know* this of the measure we employ; we must see this constant and precise relation. How can we know this? We do not perceive force as a separate existence, so as to see its proportions, and to see that these are the same with the proportions of the measures, in the same manner that Euclid sees the proportions of triangles and those of their

16
Attraction,
Repulsion,
are figurative
terms

17
Forces are
conceived
as measurable
quantities.

How measured.

their bases, and that these proportions are the same, when the triangles are of equal altitudes. How do we discover that to every magnitude which we call *force* is invariably attached a corresponding magnitude of acceleration or deflection?—Clearly. In fact, the very existence of the force is an inference that we make from the observed acceleration; and the degree of the force is, in like manner, an inference from the observed magnitude of the acceleration. Our measures are therefore necessarily connected with the magnitudes which they measure, and their proportions are the same; because the one is always an inference from the other, both in species and in degree.

18
Dynamics
is a demon-
strative
science.

It is now evident, that these disquisitions are susceptible of mathematical accuracy. Having selected our measures, and observed certain mathematical relations of those measures, every inference that we can draw from the mathematical relations of the proportions of those representations is true of the proportions of the motions; and therefore of the proportions of the forces. And thus dynamics becomes a demonstrative science, one of the *disciplina accurata*.

19. But moving forces are considered as differing also in kind; that is, in direction. We assign to the force the direction of the observed change of motion; which is not only the indication, but also the characteristic, of the changing force. We call it an *accelerating, retarding, deflecting, force*, according as we observe the motion to be accelerated, retarded, or deflected.

These denominations shew us incontestably that we have no knowledge of the forces different from our knowledge of the effects. The denominations are all either descriptive of the effects, as when we call them accelerating, penetrating, protrusive, attractive, or repulsive forces; or they are names of reference to the substances in which the accelerating, protrusive, &c. forces, are supposed to be inherent, as when we call them *magnetism, electricity, corpuscular, &c.*

20
Forces are
discovered
by their op-
position to
other for-
ces.

When I struggle with another, and feel, that in order to prevent being thrown, I must exert force, I learn that my antagonist is exerting force. This notion is transferred to matter; and when a moving power which is *known* to operate, produces no motion, we conceive it to be opposed by another equal force; the existence, agency, and intensity of which is detected and measured by these means. The quiescent state of the body is considered as a change on the state of things that would have been exhibited in consequence of the known action of one power, had this other power not acted; and this change is considered as the indication, characteristic, and measure of another power, detected in this way. Thus forces are recognised not only by the changes of motion which they produce, but also by the changes of motion which they prevent. The cohesion of matter in a string is inferred not only by its giving motion to a ball which I pull toward me by its intervention, but also by its suspending that ball, and hindering it from falling. I know that gravity is acting on the ball, which, however, does not fall. The solidity of a board is equally inferred from its stopping the ball which strikes it, and from the motion of the ball which it drives before it. In this way we learn that the particles of tangible matter cohere by means of moving forces, and that they resist compression with force; and in making this inference, we find that this corpuscular force exerted between the particles is

tual, opposite, and equal: for we must apply force equally to *a* or to *b*, in order to produce a separation or a compression. We learn their equality, by observing that no motion ensues while these mutual forces are known to act on the particles; that is, each is opposed by another force, which is neither inferior nor superior to it.

First Law
of Motion

OF THE LAWS OF MOTION.

SUCH, then, being our notions of mechanical forces, the causes of the sensible changes of motion, there will result certain consequences from them, which may be called axioms or laws of motion. Some of these may be intuitive, offering themselves to the mind as soon as the notions which they involve are presented to it. Others may be as necessary results from the relations of these notions, but may not readily offer themselves without the mediation of axioms of the first class. We shall select those which are intuitive, and may be taken for the first principles of all discussions in mechanical philosophy.

FIRST LAW OF MOTION.

Every body continues in a state of rest, or of uniform rectilinear motion, unless affected by some mechanical force.

This is a proposition, on the truth of which the whole science of mechanical philosophy ultimately depends. It is therefore to be established on the firmest foundation; and a solicitude on this head is the more justifiable, because the opinions of philosophers have been, and still are, extremely different, both with respect to the truth of this law, and with respect to the foundation on which it is built. These opinions are, in general, very obscure and unsatisfactory; and, as is natural, they influence the discussions of those by whom they are held through the whole science. Although of contradictory opinions one only can be just, and it may appear sufficient that this one be established and uniformly applied; yet a short exposition, at least, of the rest is necessary, that the greatest part of the writings of the philosophers may be intelligible, and that we may avail ourselves of much valuable information contained in them, by being able to perceive the truth in the midst of their imperfect or erroneous conceptions of it.

21.

It is not only the popular opinion that rest is the natural state of body, and that motion is something foreign to it, but it has been seriously maintained by the greatest part of those who are esteemed philosophers. They readily grant that matter will continue at rest, unless some moving force act upon it. Nothing seems necessary for matter's remaining where it is, but its continuing to exist. But it is far otherwise, say they, with respect to matter in motion. Here the body is continually changing its relations to other things; therefore the continual agency of a changing cause is necessary (by the fundamental principle of all philosophical discussion), for there is here the continual production of an effect. They say that this metaphysical argument receives complete confirmation (if confirmation of an intuitive truth be necessary) from the most familiar observation. We see that all motions, however violent, terminate in rest, and that the continual exertion of some force is necessary for their continuance.

22
Does con-
tinue n-
tion indi-
cate conti-
nued ac-
tion?

These philosophers therefore assert, that the continual action of the moving cause is essentially necessary for

23
Whim-
sical
notion
element
for
minds.

First Law of Motion.

First Law of Motion.

for the continuance of the motion: but they differ among themselves in their notions and opinions about this cause. Some maintain, that all the motions in the universe are produced and continued by the immediate agency of Deity; others affirm, that in every particle of matter there is inherent a sort of mind, the *νοῦς* and *ὑπερφυσιον* of Aristotle, which they call an ELEMENTAL MIND, which is the cause of all its motions and changes. An overweening reverence for Greek learning has had a great influence in reviving this doctrine of Aristotle. The Greek and Roman languages are affirmed to be more accurate expressions of human thought than the modern languages are. In those ancient languages, the verbs which express motion are employed both in the active and passive voice; whereas we have only the active verb *to move*, for expressing both the state of motion and the act of putting in motion. "The stone *moves* down the slope, and *moves* all the pebbles which lie in its way;" but in the ancient languages the mere state of motion is always expressed by the passive or middle voice. The accurate conception of the speakers is therefore extolled. The state of motion is expressed as it ought to be, as the result of a continual action." *Κινεῖται, movetur*, is equivalent to "it is moved." According to these philosophers, every thing which *moves* is mind, and every thing that *is moved* is body.

The argument is futile, and it is false; for the modern languages are, in general, equally accurate in this instance: "*se mouvoir*," in French; "*sich bewegen*," in German; "*dvigatsi*," in Slavonic; are all passive or reflected. And the ancients said, that "rain falls, water runs, smoke rises," just as we do. The ingenious author of *Ancient Metaphysics* has taken much pains to give us, at length, the procedures of those elementary minds in producing the ostensible phenomena of local motion; but it seems to be merely an abuse of language, and a very frivolous abuse. This elemental mind is known and characterized only by the effect which we ascribe to its action; that is, by the motions or changes of motions. Uniform and unexcepted experience shews us that these are regulated by laws as precise as those of mathematical truth. We consider nothing as more fixed and determined than the common laws of mechanism. There is nothing here that indicates any thing like spontaneity, intention, purpose; none of those marks by which mind was first brought into view; but they are very like the effects which we produce by the exertions of our corporeal forces; and we have accordingly given the name *force* to the causes of motion. It is surely much more apposite than the name mind, and conveys with much more readiness and perspicuity the very notions that we wish to convey.

We now wish to know what reason we have to think that the continual action of some cause is necessary for continuing matter in motion, or for thinking that rest is its natural state. If we pretend to draw any argument from the nature of matter, that matter must be known, as far as is necessary for being the foundation of argument. Its very existence is known only from observation; all our knowledge of it must therefore be derived from the same source.

If we take this way to come at the origin of this opinion, we shall find that experience gives us no authority for saying that rest is the natural condition of

matter. We cannot say that we have ever seen a body at rest; this is evident to every person who allows the validity of the Newtonian philosophy, and the truth of the Copernican system of the sun and planets; all the parts of this system are in motion. Nay, it appears from many observations, that the sun, with his attending planets, is carried in a certain direction, with a velocity which is very great. We have no unquestionable authority for saying that any one of the stars is absolutely fixed: but we are *certain* that many of them are in motion. Rest is therefore so rare a condition of body, that we cannot say, from any experience, that it is its natural state.

It is easy, however, to see, that it is from observation that this opinion has been derived; but the observation has been limited and careless. Our experiments in this sublunary world do indeed always require continued action of some moving force to continue the motion; and if this be not employed, we see the motions slacken every minute, and terminate in rest after no long period. Our first notions of sublunary bodies are indicated by their operation in cases where we have some interest. Perpetually seeing our own exertions necessary, we are led to consider matter as something not only naturally quiescent and inert, but sluggish, averse from motion, and prone to rest (we must be pardoned this metaphorical language, because we can find no other term). What is expressed by it, on this occasion, is precisely one of the erroneous or inadequate conceptions that are suggested to our thoughts by reason of the poverty of language. We animate matter in order to give it motion, and then we endow it with a sort of moral character in order to explain the appearance of those motions.

But more extended observation has made men gradually desert their first opinions, and at last allow that matter has no peculiar aptitude to rest. All the retardations that we *observe* have been discovered, one after another, to have a distinct reference to some external circumstances. The diminution of motion is always observed to be accompanied by the removal of obstacles, as when a ball moves through sand, or water, or air; or it is owing to opposite motions which are destroyed; or it is owing to roughness of the path, or to friction, &c. We find that the more we can keep those things out of the way, the less are the motions diminished. A pendulum will vibrate but a short while in water; much longer in air; and in the exhausted receiver, it will vibrate a whole day. We know that we cannot remove *all* obstacles; but we are led by such observations to conclude that, if they *could be completely removed*, our motions would continue for ever. And this conclusion is almost demonstrated by the motions of the heavenly bodies, to which we know of no obstacles, and which we really observe to retain their motions for many thousand years without the smallest sensible diminution.

Another set of philosophers maintain an opinion directly opposite to that of the inactivity of matter, and assert, that it is essentially active, and continually changing its state. Faint traces of this are to be found in the writings of Plato, Aristotle, and their commentators. Mr Leibnitz is the person who has treated this question most systematically and fully. He supposes every particle of matter to have a principle of individuality, which he therefore calls a MONAD. This monad

24 Action not necessary for the continuance of motion.

25.

26.

27. Inactivity of matter denied by Leibnitz.

what.

First Law of Motion.

nad has a sort of perception of its situation in the universe, and of its relation to every other part of this universe. Lastly, he says that the monad acts on the material particle, much in the same way that the soul of man acts on his body. It modifies the motion of the material atom (in conformity, however, to unalterable laws), producing all those modifications of motion that we observe. Matter therefore, or at least particles of matter, are continually active, and continually changing their situation.

This opinion ill founded.

It is quite unnecessary to enter on a formal confutation of Mr Leibnitz's system of monads, which differs very little from the system of elemental minds, and is equally whimsical and frivolous; because it only makes the unlearned reader stare, without giving him any information. Should it even be granted, it would not, any more than the action of animals, invalidate the general proposition which we are endeavouring to establish as the fundamental law of motion. Those powers of the monads, or of the elemental minds, are the causes of all the changes of motion; but the mere material particle is subject to the law, and requires the exertion of the monad in order to exhibit a change of motion.

23 Some philosophers deduce this law of motion from the want of a determining cause.

A third sect of philosophers, at the head of which we may place Sir Isaac Newton, maintain the doctrine enounced in the proposition. But they differ much in respect of the foundation on which it is built.

Some assert that its truth flows from the nature of the thing. If a body be at rest, and you assert that it will not remain at rest, it must move in some one direction. If it be in motion in any direction, and with any velocity, and do not continue its equable, rectilinear, motion, it must either be accelerated or retarded; it must turn either to one side, or to some other side. The event, whatever it be, is individual and determinate; but no cause which can determine it is supposed: therefore the determination cannot take place, and no change will happen in the condition of the body with respect to motion. It will continue at rest, or persevere in its rectilinear and equable motion.

But considerable objections may be made to this argument, of *sufficient reason*, as it is called. In the immensity and perfect uniformity of space and time, there is no determining cause why the visible universe should exist in the place in which we see it rather than in another, or at this time rather than at another. Nay, the argument seems to beg the question. A cause of determination is required as essentially necessary—a determination may be without a cause, as well as a motion without a cause.

29 Others deduce it from experience.

Other philosophers, who maintain this doctrine, consider it merely as an experimental truth; and proofs of its universality are innumerable.

When a stone is thrown from the hand, we press it forward while in the hand, and let it go when the hand has acquired the greatest rapidity of motion that we can give it. The stone continues in that state of motion which it acquired gradually along with the hand. We can throw a stone much farther by means of a sling; because, by a very moderate motion of the hand, we can whirl the stone round till it acquire a very great velocity, and then we let go one of the strings, and the stone escapes, *by continuing* its rapid motion. We see it still more distinctly in shooting an arrow from a bow. The string presses hard on the notch of the arrow, and

it yields to this pressure and goes forward. The string alone would go faster forward. It therefore *continues* to press the arrow forward, and accelerates its motion. This goes on till the bow is as much un bent as the string will allow. But the string is now a straight line. It came into this position with an accelerated motion, and it therefore goes a little beyond this position, but with a retarded motion, being checked by the bow. But there is nothing to check the arrow; therefore the arrow quits the string, and flies away.

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These are simple cases of perseverance in a state of motion, where the procedure of nature is so easily traced that we perceive it almost intuitively. It is no less clear in other phenomena which are more complicated; but it requires a little reflection to trace the process. We have often seen an equestrian showman ride a horse at a gallop, standing on the saddle, and stepping from it to the back of another horse that gallops alongside at the same rate; and he does this seemingly with as much ease as if the horses were standing still. The man has the same velocity with the horse that gallops under him, and keeps this velocity while he steps to the back of the other. If that other were standing still, the man would fly over his head. And if a man should step from the back of a horse that is standing still to the back of another that gallops past him, he would be left behind. In the same manner, a slack wire-dancer tosses oranges from hand to hand while the wire is in full swing. The orange, swinging along with the hand, retains the velocity; and when in the air follows the hand, and falls into it when it is in the opposite extremity of its swing. A ball, dropped from the mast-head of a ship that is sailing briskly forward, falls at the foot of the mast. It retains the motion which it had while in the hand of the person who dropped it, and follows the mast during the whole of its fall.

We also have familiar instances of the perseverance of a body in a state of rest. When a vessel filled with water is drawn suddenly along the floor, the water dashes over the posterior side of the vessel. It is left behind. In the same manner, when a coach or boat is dragged forward, the persons in it find themselves strike against the hinder part of the carriage or boat. Properly speaking, it is the carriage that strikes on them. In like manner, if we lay a card on the tip of the finger, and a piece of money on the card, we may nick away the card, by hitting it neatly on its edge; but the piece of money will be left behind, lying on the tip of the finger. A ball will go through a wall and fly onward; but the wall is left behind. Buildings are thrown down by earthquakes; sometimes by being tossed from their foundations, but more generally by the ground on which they stand being hastily drawn sideways from under them, &c.

But common experience seems insufficient for establishing this fundamental proposition of mechanical philosophy. We must, on the faith of the Copernican system, grant that we never saw a body at rest, or in uniform rectilinear motion; yet this seems absolutely necessary before we can say that we have established this proposition experimentally.

What we imagine, in our experiments, to be putting a body, formerly at rest, into motion, is, in fact, only changing a most rapid motion, not less, and probably much greater, than 90,000 feet per second. Suppose a cannon pointed east, and the bullet discharged at noon

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day with 60 times greater velocity than we have ever been able to give it. It would appear to set out with this unmeasurable velocity to the eastward; to be gradually retarded by the resistance of the air, and at last brought to rest by hitting the ground. But, by reason of the earth's motion round the sun, the fact is quite the reverse. Immediately before the discharge, the ball was moving to the westward with the velocity of 90,000 feet per second nearly. By the explosion of the powder, and its pressure on the ball, some of this motion is destroyed, and at the muzzle of the gun, the ball is moving slower, and the cannon is hurried away from it to the westward. The air, which is also moving to the westward 90,000 feet in a second, gradually communicates motion to the ball, in the same manner as a hurricane would do. At last (the ball dropping all the while) some part of the ground hits the ball, and carries it along with it.

Other observations must therefore be resorted to, in order to obtain an experimental proof of this proposition. And such are to be found. Although we cannot measure the absolute motions of bodies, we can observe and measure accurately their relative motions, which are the differences of their absolute motions. Now, if we can shew experimentally, that bodies shew equal tendencies to resist the augmentation and the diminution of their relative motions, they, *ipso facto*, shew equal tendencies to resist the augmentation or diminution of their absolute motions. Therefore let two bodies, A and B, be put into such a situation, that they cannot (by reason of their impenetrability, or the actions of their mutual powers) persevere in their relative motions. The change produced on A is the effect and the measure of B's tendency to persevere in its former state; and therefore the proportion of these changes will shew the proportion of their tendencies to maintain their former states. Therefore let the following experiment be made at noon.

Let A, apparently moving westward three feet per second, hit the equal body B apparently at rest. Suppose, 1st, That A impels B forward, without any diminution of its own velocity. This result would shew that B manifests no tendency to maintain its motion unchanged, but that A retains its motion undiminished.

2^{dly}, Suppose that A stops, and that B remains at rest. This would shew that A does not resist a diminution of motion, but that B retains its motion unaugmented.

3^{dly}, Suppose that both move westward with the velocity of one foot per second. The change on A is a diminution of velocity, amounting to two feet per second. This is the effect and the measure of B's tendency to maintain its velocity unaugmented. The change on B is an augmentation of one foot per second made on its velocity; and this is the measure of A's tendency to maintain its velocity undiminished. This tendency is but half of the former; and this result would shew, that the resistance to a diminution of velocity is but half of the resistance to augmentation. It is perhaps but one quarter; for the change on B has produced a double change on A.

4^{thly}, Suppose that both move westward at the rate of $1\frac{1}{2}$ feet per second. It is evident that their tendencies to maintain their states unchanged are now equal.

5^{thly}, Suppose A = 2 B, and that both move, after the collision, two feet per second, B has received an

addition of two feet per second to its former velocity. This is the effect and the measure of A's whole tendency to retain its motion undiminished. Half of this change on B measures the persevering tendency of the half of A; but A, which formerly moved with the apparent or relative velocity three, now moves (by the supposition) with the velocity two, having lost a velocity of one foot per second. Each half of A therefore has lost this velocity, and the whole loss of motion is two. Now this is the measure of B's tendency to maintain its former state unaugmented; and this is the same with the measure of A's tendency to maintain its own former state undiminished. The conclusion from such a result would therefore be, that bodies have equal tendencies to maintain their former states of motion without augmentation and without diminution.

What is supposed in the 4th and 5th cases is really the result of all the experiments which have been tried; and this law regulates all the changes of motion which are produced by the mutual actions of bodies in impulses. This assertion is true without exception or qualification. Therefore it appears that bodies have no preferable tendency to rest, and that no fact can be adduced which should make us suppose that a motion once begun should suffer any diminution without the action of a changing cause.

But we must now observe, that this way of establishing the first law of motion is very imperfect, and altogether unfit for rendering it the fundamental principle of a whole and extensive science. It is subject to all the inaccuracy that is to be found in our best experiments; and it cannot be applied to cases where scrupulous accuracy is wanted, and where no experiment can be made.

Let us therefore examine the proposition by means of the general principles adopted in the article PHILOSOPHY, *Encycl.* which contain the foundation of all our knowledge of active nature. These principles will, we imagine, give a decision of this question that is speedy and accurate, shewing the proposition to be an axiom or intuitive consequence of the relations of those ideas which we have of motion, and of the causes of its production and changes.

It has been fully demonstrated that the powers or forces, of which we speak so much, are never the immediate objects of our perception. Their very existence, their kind, and their degree, are instinctive inferences from the motions which we observe and class. It evidently follows from this experimental and universal truth, 1st, That where no change of motion is observed, no such inference is made; that is, no power is supposed to act. But whenever any change of motion is observed, the inference is made; that is, a power or force is supposed to have acted.

In the same form of logical conclusion, we must say that, 2^{dly}, When no change of motion is supposed or thought of, no force is supposed; and that whenever we suppose a change of motion, we, in fact, though not in terms, suppose a changing force. And, on the other hand, whenever we suppose the action of a changing force, we suppose the change of motion; for the action of this force, and the change of motion, is one and the same thing. We cannot think of the action without thinking of the indication of that action; that is, the change of motion.—In the same manner, when we do not think of a changing force, or suppose that there is

But experience is not the proper foundation of an axiom.

Logical proof.

Experiments proper for the purpose.

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of Motion.

It is a law
of human
thought,

no action of a changing force, we, in fact, though not in terms, suppose that there is no indication of this changing force; that is, that there is no change.

Whenever, therefore, we suppose that no mechanical force is acting on a body, we, in fact, suppose that the body continues in its former condition with respect to motion. If we suppose that nothing accelerates, or retards, or deflects the motion, we suppose that it is not accelerated, nor retarded, nor deflected. Hence follows the proposition in express terms—*We suppose that the body continues in its former state of rest or motion, unless we suppose that it is changed by some mechanical force.*

Thus it appears, that this proposition is not a matter of experience or contingency, depending on the properties which it has pleased the Author of Nature to bestow on body: it is, to us, a necessary truth. The proposition does not so much express any thing with regard to body, as it does the operations of our mind when contemplating body. It may perhaps be essential to body to move in some particular direction. It may be essential to body to stop as soon as the moving cause has ceased to act; or it may be essential to body to diminish its motion gradually, and finally come to rest. But this will not invalidate the truth of this proposition. These circumstances in the nature of body, which render those modifications of motion essentially necessary, are the causes of those modifications; and, in our study of nature, they will be considered by us as changing forces, and will be known and called by that name. And if we should ever see a particle of matter in such a situation that it is affected by those essential properties alone, we shall, from observation of its motion, discover what those essential properties are.

And almost
an identical
proposition.

This law turns out at last to be little more than a tautological proposition: But mechanical philosophy, as we have defined it, requires no other sense of it: for, even if we should suppose that body, of its own nature, is capable of changing its state, this change must be performed according to some law which characterises the nature of body; and the knowledge of the law can be had in no other way than by observing the deviations from uniform rectilinear motion. It is therefore indifferent whether those changes are derived from the nature of the thing, or from external causes: for in order to consider the various motions of bodies, we must first consider this nature of matter as a mechanical affection of matter, operating in every instance; and thus we are brought back to the law enounced in this proposition. This becomes more certain when we reflect that the external causes (such as gravity or magnetism), which are acknowledged to operate changes of motion, are equally unknown to us with this essential original property of matter, and are, like it, nothing but inferences from the phenomena.

The above very diffuse discussions may appear superfluous to many readers, and even cumbersome; but we trust that the philosophical reader will excuse our anxiety on this head, when he reflects on the complicated, indistinct, and inaccurate notions commonly had of the subject; and more especially when he observes, that of those who maintain the truth of this fundamental proposition, as we have enounced it, many (and they too of the first eminence), reject it in fact, by combining it with other opinions which are inconsistent with it, nay, which contradict it in express terms. We may even

include Sir Isaac Newton in the number of those who have at least introduced modes of expression which mislead the minds of incautious persons, and suggest inadequate notions, incompatible with the pure doctrine of the proposition. Although, in words, they disclaim the doctrine that rest is the natural state of body, and that force is necessary for the continuation of its motion, yet in words they (and most of them in thought) likewise abet that doctrine: for they say, that there resides in a moving body a *power* or *force*, by which it perseveres in its motion. They call it the *vis insita*, the *INHERENT FORCE OF A MOVING BODY*. This is surely giving up the question: for if the motion is supposed to be continued in consequence of a force, that force is *supposed* to be exerted; and it is supposed, that if it were not exerted, the motion would cease; and therefore the proposition must be false. Indeed it is sometimes expressed so as seemingly to ward off this objection. It is said that the body continues in uniform rectilinear motion, unless affected by some *external cause*. But this way of speaking obliges us, at first setting out in natural philosophy, to assert that gravity, magnetism, electricity, and a thousand other mechanical powers, are external to the matter which they put in motion. This is quite improper: It is the business of philosophy to discover whether they be external or not; and if we assert that they are, we have no principles of argumentation with those who deny it. It is this one thing that has filled the study of nature with all the jargon of æthers and other invisible intangible fluids, which has disgraced philosophy, and greatly retarded its progress.

We must observe, that the terms *vis insita*, inherent *force*, are very improper. There is no dispute among philosophers in calling every thing a force that produces a change of motion, and in inferring the action of such a force whenever we observe a change of motion. It is surely incongruous to give the same name to what has not this quality of producing a change, or to infer (or rather to suppose) the energy of a force when no change of motion is observed. This is one among many instances of the danger of mistake when we indulge in analogical discussions. All our language, at least, on this subject is analogous. I feel, that in order to oppose animal force, I must exert force. But I must exert force in order to oppose a body in motion: Therefore I imagine that the moving body possesses force. A bent spring will drive a body forward by unbending: Therefore I say that the spring exerts force. A moving body impels the body which it hits: Therefore I say, that the impelling body possesses and exerts force. I imagine farther, that it possesses force only by being in motion, or because it is in motion; because I do not find that a quiescent body will put another into motion by touching it. But we shall soon find this to be false in many, if not in all cases, and that the communication of motion depends on the mere vicinity, and not on the motion of the impelling body; yet we ascribe the exertion of the *vis insita* to the circumstance of the continued motion. We therefore conceive the force as arising from, or as consisting in, the impelling body's being in motion; and, with a very obscure and indistinct conception of the whole matter, we call it *the force by which the body preserves itself in motion*. Thus, taking it for granted that a force resides in the body, and being obliged to give it some office, this is the only one that we can think of.

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Vis insita,
inherent
force, are
improper
terms in
their usual
acceptation.

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of Motion.

But philosophers imagine that they perceive the necessity of the exertion of a force in order to the continuation of a motion. Motion (say they) is a continued action; the body is every instant in a new situation; there is the continual production of an effect, therefore the continual action of a cause.

But this is a very inaccurate way of thinking. We have a distinct conception of motion; and we conceive that there is such a thing as a moving cause, which we distinguish from all other causes by the name *force*. It produces motion. If it does this, it produces the character of motion, which is a continual change of place. Motion is not action, but the effect of an action; and this action is as incomplete in the instant immediately succeeding the beginning of the motion as it is a minute after. The subsequent change of place is the continuation of an effect already produced. The *immediate* effect of the moving force is a DETERMINATION, by which, if not hindered, the body would go on for ever from place to place. It is in this determination only that the state or condition of the body can differ from a state of rest; for in any instant, the body does not describe any space, but has a determination, by which it will describe a certain space uniformly in a certain time. Motion is a condition, a state, or mode of existence, and no more requires the continued agency of the moving cause than yellowness or roundness does. It requires some chemical agency to change the yellowness to greenness; and it requires a mechanical cause or a force to change this motion into rest. When we see a moving body stop short in an instant, or be gradually, but quickly, brought to rest, we never fail to speculate about a cause of this cessation or retardation. The case is no way different in itself although the retardation should be extremely slow. We should always attribute it to a cause. It requires a cause to put a body out of motion as much as to put it into motion. This cause, if not external, must be found in the body itself; and it must have a self-determining power, and may as well be able to put itself into motion as out of it.

If this reasoning be not admitted, we do not see how any effect can be produced by any cause. Every effect supposes something *done*; and any thing done implies that the thing done may remain till it be *undone* by some other cause. Without this, it would have no existence. If a moving cause did not produce continued motion by its instantaneous action, it could not produce it by any continuance of that action; because in no instant of that action does it produce continued motion.

We must therefore give up the opinion, that there resides in a moving body a force by which it is kept in motion; and we must find some other way of explaining that remarkable difference between a moving body and a body at rest, by which the first causes other bodies to move by hitting them, while the other does not do this by merely touching them. We shall see, with the clearest evidence, that motion is necessary in the impelling body, in order that it may permit the forces inherent in one or both bodies to continue this pressure long enough for producing a sensible or considerable motion. But these moving forces are inherent in bodies, whether they are in motion or at rest.

The foregoing observations shew us the impropriety of the phrase *communication of motion*. By thus reflect-

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of Motion.

ing on the notions that are involved in the general conception of one body being made to move by the impulse of another, we perceive that there is nothing individual transferred from the one body to the other. The determination to motion, indeed, existed only in the impelling body before collision; whereas, afterwards, both bodies are so conditioned or determined. But we can form no notion of the thing transferred. With the same metaphysical impropriety, we speak of the communication of joy, of fever.

Kepler introduced a term *INERTIA, VIS INERTIÆ*, So is *vis inertiae*. into mechanical philosophy; and it is now in constant use. But writers are very careless and vague in the notions which they affix to these terms. Kepler and Newton seem generally to employ it for expressing the fact, the perseverance of the body in its present state of motion or rest: but they also frequently express by it something like an indifference to motion or rest, *manifested by its requiring the same quantity of force to make an augmentation of its motion as to make an equal diminution of it*. The popular notion is like that which we have of actual resistance; and it always implies the notion of force exerted by the resisting body. We suppose this to be the exertion of the *vis insita*, or the *inherent force* of a body in motion. But we have the same notion of resistance from a body at rest which we set in motion. Now surely it is in direct contradiction to the common use of the word *force*, when we suppose resistance from a body at rest; yet *vis inertiae* is a very common expression. Nor is it more absurd (and it is very absurd) to say, that a body maintains its state of rest by the exertion of a *vis inertiae*, than to say, that it maintains its state of motion by the exertion of an *inherent force*. We should avoid all such metaphorical expressions as *resistance, indifference, sluggishness, or proneness to rest* (which some express by *inertia*), because they seldom fail to make us indulge in metaphorical notions, and thus lead us to misconceive the *modus operandi*, or procedure of nature.

There is *no resistance whatever observed* in these phenomena; for the force employed always produces its complete effect. When I throw down a man, and find that I have employed no more force than was sufficient to throw down a similar and equal mass of dead matter, I know by this that he *has not resisted*; but I conclude that he *has resisted*, if I have been obliged to employ much more force. There is therefore no resistance, properly so called, when the exerted force is observed to produce its full effect. To say that there is resistance, is therefore a real misconception of the way in which mechanical forces have operated in the collision of bodies. There is no more resistance in these cases than in any other natural changes of condition. We are guilty, however, of the same impropriety of language in other cases, where the cause of it is more evident. We say that colours in grain *resist* the action of soap and of the sun, but that Prussian blue does not. We all perceive, that in this expression the word resistance is entirely figurative: and we should say that Prussian blue *resists* soap, if we are right in saying that a body resists any force employed to change its state of motion; for soap must be employed to discharge or change the colour; and *it does change it*. Force must be employed to change a motion; and *it does change it*. The impropriety, both of thought and language, is plain in the one case, and it is no less real in the other. Both

33
Motion is
not the
continual
production
of an effect.

34
Communi-
cation of
motion is
an improp-
er phrase,

35
So is *vis
inertiae*.

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of Motion.

of the terms, *inherent force* and *inertia*, may be used with safety for abbreviating language, if we be careful to employ them only for expressing, *either the simple fact of persevering in the former state, or the necessity of employing a certain determinate force, in order to change that state, and if we avoid all thought of resistance.*

36
Deviations
from uni-
form recti-
lineal mo-
tion are the
only indica-
tions of
force.

From the whole of this discussion, we learn, that the deviations from uniform motions are the indications of the existence and agency of mechanical forces, and that they are the only indications. The indication is very simple, mere change of place; it can therefore indicate nothing but what is very simple, the something competent to the production of the very motion that we observe. And when two changes of motion are precisely similar, they indicate the same thing. Suppose a mariner's compass on the table, and that by a small tap with my finger I cause the needle to turn off from its quiescent position 10 degrees. I can do the same thing by bringing a magnet near it; or by bringing an electrified body near it; or by the unbending of a fine spring pressing it aside; or by a puff of wind; or by several other methods. In all these cases, the indication is the same; therefore the thing indicated is the same, namely, a certain intensity and direction of a moving power. How it operates, or in what manner it exists and exerts itself in these instances, outwardly so different, is not under consideration at present. Impulsiveness, intensity, and direction, are all the circumstances of resemblance by which the affections of matter are to be characterised; and it is to the discovery and determination of these alone that our attention is now to be directed. We are directed in this research by the

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Every change of motion is proportional to the force impressed, and is made in the direction of that force.

37.

This law also may almost be considered as an identical proposition; for it is equivalent to saying, that the changing force is to be measured by the change which it produces, and that the direction of this force is the direction of the change. Of this there can be no doubt, when we consider the force in no other sense than that of the cause of motion, paying no attention to the form or manner of its exertion. Thus, when a pellet of tow is shot from a pop-gun by the expansion of the air compressed by the rammer, or where it is shot from a toy pistol by the unbending of the coiled wire, or when it is nicked away by the thumb like a marble—if, in all these cases, it moves off in the same direction, and with the same velocity, we cannot consider or think of the force, or at least of its exertion, as any how different. Nay, when it is driven forward by the instantaneous percussion of a smart stroke, although the manner of producing this effect (if possible) is essentially different from what is conceived in the other cases, we must still think that the propelling force, considered as a propelling force, is one and the same. In short, this law of motion, as thus expressed by Sir Isaac Newton, is equivalent to saying, "That we take the changes of motion as the measures of the changing forces, and the direction of the change for the indication of the direction of the forces." For no reflecting person can pretend to say, that it is a deduction from the acknowledged principle, that effects are proportional to their causes. We do not affirm this law, from having observed the proportion of the forces and the proportion of the

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of Motion.

changes, and that these proportions are the same; and from having observed that this has obtained through the whole extent of our study of nature. This would indeed establish it as a physical law, an universal fact; and it is, in fact, so established. But this does not establish it as a law of motion, according to our definition of that term; as a law of human thought, the result of the relations of our ideas, as an intuitive truth. The injudicious attempts of philosophers to prove it as a matter of observation, have occasioned the only dispute that has arisen in mechanical philosophy. It is well known that a bullet, moving with double velocity, penetrates four times as far. Many other similar facts corroborate this: and the philosophers observe, that four times the force has been expended to generate this double velocity in the bullet; it requires four times as much powder. In all the examples of this kind, it would seem that the ratio of the forces employed has been very accurately ascertained; yet this is the invariable result. Philosophers, therefore, have concluded, that moving forces are not proportional to the velocities which they produce, but to the squares of those velocities. It is a strong confirmation, to see that the bodies in motion seem to possess forces in this very proportion, and produce effects in this proportion; penetrating four times as deep when the velocity is only twice as great, &c.

But if this be a just estimation, we cannot reconcile it to the concession of the same philosophers, who grant that the velocity is proportional to the force impressed, in the cases where we have no previous observation of the ratio of the forces, and of its equality to the ratio of the velocities. This is the case with gravity, which these philosophers always measure by its accelerating power, or of the velocity which it generates in a given time. And this cannot be refused by them; for cases occur, where the force can be measured, in the most natural manner, by the actual pressure which it exerts. Gravity is thus measured by the pressure which a stone exerts on its supports. A weight which at Quito will pull out the rod of a spring itelyard to the mark 312, will pull it to 313 at Spitzbergen. And it is a fact, that a body will fall 313 inches at Spitzbergen in the same time that it falls 312 at Quito. Gravitation is the cause both of the pressure and the fall; and it is a matter of unexcepted observation, that they have always the same ratio. The philosophers who have so strenuously maintained the other measure of forces, are among the most eminent of those who have examined the motions produced by gravity, magnetism, electricity, &c.; and they never think of measuring those forces any other way than by the velocity. It is in this way that the whole of the celestial phenomena are explained in perfect uniformity with observation, and that the Newtonian philosophy is considered as a demonstrative science.

There must, therefore, be some defect in the principle on which the other measurement of forces is built, or in the method of applying it. Pressure is undoubtedly the immediate and natural measure of force; yet we know that four springs, or a bow four times as strong, give only a double velocity to an arrow.

The truth of our law rests on this only, that we assume the changes of motion as the measure of the changing forces; or, at least, as the measures of their exertions in producing motion. In fact, they are the measures only

^{Second Law of Motion} of a certain circumstance, in which the actions of very different natural powers may resemble each other; namely, the competency to produce motion. They do not, perhaps, measure their competency to produce heat, or even to bend springs. We can surely consider this apart from all other circumstances; and it is worthy of separate consideration. Let us see what can be, and what ought to be, deduced from this way of treating the subject.

sible to make one and the same change on it. The same change may therefore be made at the very instant that the motion is at an end. In this case, the change is the very motion which the body acquires from the changing force. Therefore, in this case also, we must say, that a change of motion is itself a motion, and that it is the motion which the force would produce in a body that was previously at rest.

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³⁸ The motion of a body may certainly remain unchanged. If the direction and velocity remain the same, we perceive no circumstance in which its condition, with respect to motion, differs. Its change of place or situation can make no difference; for this is implied in the very circumstance of the body's being in motion.

⁴¹ The result of these observations is evidently this, that we must ascertain, in every instance, what is the change of motion, and mark it by characters that are conspicuous and distinguishing; and this mark and measure of change must be a motion: Then we must say, that the changing force is that which would produce this motion in a body previously at rest. We must see how this is manifest, as a motion, in the difference between the former motion and the new motion; and, on the other hand, we must see how the motion producible in a quiescent body may be so combined with a motion already existing, as to exhibit a new motion, in which the agency of the changing force may appear.

⁴¹ How ascertained and measured.

But if either the velocity or direction change, then surely is its mechanical condition no longer the same; a force has acted on it, either intrinsic or from without, either accelerating, or retarding, or deflecting it. Supposing the direction to remain the same, its difference of condition can consist in nothing but its difference of velocity. This is the only circumstance in which its condition can differ, as it passes through two different points of its rectilinear path. It is this determination by which the body will describe a certain determinate space uniformly in a given time, which defines its condition as a moving body: the changes of this determination are the measures of their own causes;—and to those causes we have given the name *force*. Those causes may reside in other bodies, which may have other properties, characterised and measured by other effects. Pressure may be one of those properties, and may have its own measures; these may, or may not, have the same proportion with that property which is the cause of a change of velocity: and therefore changes of velocity may not be a measure of pressure. This is a question of fact, and requires observation and experience; but, in the mean time, velocity, and the change of velocity, is the measure of moving force and of changing force. When therefore the change of velocity is the same, whatever the previous velocity may be, the changing force must be considered as the same: therefore, finally, if the previous velocity is nothing, and consequently the change on that body is the very velocity or motion that it acquires, we must say, that the force which produces a certain change in the velocity of a moving body, is the same with the force which would impart to a body at rest a velocity equal to this change or difference of velocity produced on the body already in motion.

Suppose a ship at anchor in a stream; while one man walks forward on the quarter-deck at the rate of two miles per hour, another walks from stem to stern at the same rate, a third walks athwart ship, and a fourth stands still. Let the ship be supposed to cut or part her cable, and float down the stream at the rate of three miles per hour. We cannot conceive any difference in the change made on each man's motion in absolute space; but their motions are now exceedingly different from what they were: the first man, whom we may suppose to have been walking westward, is now moving eastward one mile per hour; the second is moving eastward four miles per hour; and the third is moving in an oblique direction, about three points north or south of due east. All have suffered the same change of condition with the man who had been standing still. He has now got a motion eastward three miles per hour. In this instance, we see very well the circumstance of sameness that obtains in the change of these four conditions. It is the motion of the ship, which is blended with the other motions. But this circumstance is equally present whenever the same previous motions are changed into the same new motions. We must learn to explicate this; which we shall do, by considering the manner in which the motion of the ship is blended with each of the mens motions.

^{39.} This manner of estimating force is in perfect conformity to our most familiar notions on these subjects. We conceive the weight or downward pressure of a body as the cause of its motion downwards; and we conceive it as belonging to the body at all times, and in all places, whether falling, or rising upwards, or describing a parabola, or lying on a table; and, accordingly, we observe, that in every state of motion it receives equal changes of velocity in the same, or an equal time, and all in the direction of its pressure.

⁴² This kind of combination has been called the COMPOSITION OF MOTION; because, in every point of the motion really pursued, the two motions are to be found. ⁴² Composition of motion.

The fundamental theorem on this subject is this:—Two uniform motions in the sides of a parallelogram compose an uniform motion in the diagonal.

^{40.} All that we have now said of a change of velocity might be repeated of a change of direction. It is surely possible that the same change of direction may be made on any two motions. Let one of the motions be considered as growing continually slower, and terminating in rest. In every instant of this motion it is pos-

Suppose that a point A (fig. 1.) describes AB uniformly in some given time, while the line AB is carried uniformly along AC in the same time, keeping always parallel to its first position AB. The point A, by the combination of these motions, will describe AD, the diagonal of the parallelogram ABDC, uniformly in the same time. Plate XXI.

For it is plain, that the velocities in AB and AC are proportional to AB and AC, because they are uniformly described in the same time. When the point has got to E, the middle of AB, the line AB has got into the situation GH, half way between AB and CD,

Second Law
of Motion.

and the point E is in the place *e*, the middle of GH. Draw *EeL* parallel to AC. It is plain that the parallelograms ABDC and AE*e*AG are similar; because AE and AG are the halves of AB and AC, and the angle at A is common to both. Therefore, by a proposition in the Elements, they are about the same diagonal, and the point *e* is in the diagonal AD. In like manner, it may be shewn, that when A has described AF, $\frac{1}{2}$ ths of AB, the line AB will be in the situation IK, so that AI is $\frac{1}{2}$ ths of AC, and the point *f*, in which A is now found, is in the diagonal AD. It will be the same in whatever point of AB the describing point A be supposed to be found. The line AB will be on a similar point of AC; and the describing point will be in the diagonal AD.

Moreover, the motion in AD is uniform: for A*e* is described in the time of describing AE; that is, in half the time of describing AB, or in half the time of describing AD. In like manner, Af is described in $\frac{1}{3}$ ths of the time of describing AD, &c. &c.

Lastly, the velocity in the diagonal AD is to the velocity in either of the sides as AD is to that side. This is evident, because they are uniformly described in the same time.

This is justly called a composition of the motions AB and AC, as will appear by considering it in the following manner: Let the lines AB, AC be conceived as two material lines like wires. Let AB move uniformly from the situation AB into the situation CD, while AC moves uniformly into the situation BD. It is plain that their intersection will always be found on AD. The point *e*, for example, is a point common to both lines. Considered as a point of EL, it is then moving in the direction *eH* or AB; and, considered as a point of GH, it is moving in the direction *eL*. Both of these motions are therefore blended in the motion of the intersection along AD. We can conceive a small ring at *e*, embracing loosely both of the wires. This material ring will move in the diagonal, and will really partake of both motions.

Thus we see how the motion of the ship is actually blended with the motions of the three men; and the circumstance of sameness which is to be found in the four changes of motion is this motion of the ship, or of the man who was standing still. By composition with each of the three former motions, it produces each of the three new motions. Now, when each of two primitive motions is the same, and each of the new motions is the same, the change is surely the same. If one of the changes has been brought about by the actual composition of motions, we know precisely what that change is; and this informs us what the other is, in whatever way it was produced. Hence we infer, that,

When a motion is any how changed, the change is that motion which, when compounded with the former motion, will produce the new motion. Now, because we assume the change as the measure and characteristic of the changing force, we must do so in the present instance; and we must say,

That the changing force is that which will produce in a quiescent body the motion which, by composition with the former motion of a body, will produce the new motion.

And, on the other hand,

When the motion of a body is changed by the action of any force, the new motion is that which is compounded of

the former motion, and of the motion which the force would produce in a quiescent body.

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of Motion.

When a force changes the direction of a motion, we see that its direction is transverse in some angle BAC; because a diagonal AD always supposes two sides. As we have distinguished any change of direction by the term DEFLECTION, we may call the transverse force a DEFLECTING FORCE.

Deflecting
force.

In this way of estimating a change of motion, all the characters of both motions are preserved, and it expresses every circumstance of the change; the mere change of direction, or the angle BAD, is not enough, because the same force will make different angles of deflection, according to the velocity of the former motion, or according to its direction: but in this estimation, the full effect of the deflecting force is seen; it is seen as a motion; for when half of the time is elapsed, the body is at *e* instead of E; when three-fourths are elapsed, it is at *f* instead of F; and at the end of the time it is at D instead of B. In short, the body has moved uniformly away from the points at which it would have arrived independent of the change; and this motion has been in the same direction, and at the same rate, as if it had moved from A to C by the changing force alone. Each force has produced its full effect; for when the body is at D, it is as far from AC as if the force AC had not acted on it; and it is as far from AB as it would have been by the action of AC alone.

For all these reasons, therefore, it is evident, that if we are to abide by our measure and character of force as a mere producer of motion, we have selected the proper characteristic and measure of a changing force: and our descriptions, in conformity to this selection, must be agreeable to the phenomena of nature, and retain the accuracy of geometrical procedure; because, on the other hand, the results which we deduce from the supposed influence of those forces are formed in the same mould. It is not even requisite that the real exertions of the natural forces, such as pressure of various kinds, &c. shall follow these rules; for their deviations will be considered as new forces, although they are only indications of the differences of the real forces from our hypothesis. We have obtained the precious advantage of mathematical investigation, by which we can examine the law of exertion which characterises every force in nature.

On these principles we establish the following fundamental elementary proposition, of continual and indispensable use in all mechanical inquiries.

If a body or material particle be subjected at the same time to the action of two moving forces, each of which would separately cause it to describe the side of a parallelogram uniformly in a given time, the body will describe the diagonal uniformly in the same time.

45
Fundamental
theorem.

For the body, whose motion AB was changed into AD, had gotten its motion by the action of some force. It was moving along NAB; and, when it reached the point A, the force AC acted on it. The primitive motion is the same, or the body is in the same condition in every instant of the primitive motion. It may have acquired this motion when it was in N, or when at O, or any other point of NA. In all these cases, if AC act on it when it is in A, it will always describe AD; therefore it will describe AD when it acquires the primitive motion also in A; that is, if the two forces

43
Its mark
and measure.

44
Changing
force.

Its effect.

ces

6. *Second Law of Motion* ces act on it at one and the same instant. The demonstration may be neatly expressed thus: The change induced by each force on the motion produced by the other, is the motion which it would produce in the body if previously at rest. Therefore the motion resulting from joint action is the motion which is compounded of these two motions; or it is a motion in the diagonal of the parallelogram, of which these motions are the sides.

Composition of Forces. This is called the COMPOSITION OF FORCES. The forces which produce the motions along the sides of the parallelogram are called the SIMPLE FORCES, or the CONSTITUENT FORCES; and the force which would alone produce the motion along the diagonal is called the COMPOUND FORCE, the RESULTING FORCE, the EQUIVALENT FORCE.

46. On the other hand, the force which produces a motion along any line whatever, may be conceived as resulting from the combined action of two or more forces. We may know or observe it to be so; as when we see a lighter dragged along a canal by two horses, one on each side. Each pulls the boat directly toward himself in the direction of the track-rope; the boat cannot go both ways, and its real motion, whatever it is, results from this combined action. This might be produced by a single force; for example, if the lighter be dragged along the canal by a rope from another lighter which precedes it, being dragged by one horse, aided by the helm of the foremost lighter. Here the real force is not the resulting, or the compound, but the equivalent force.

Resolution of forces. This view of a motion, mechanically produced, is called the RESOLUTION OF FORCES. The force in the diagonal is said to be resolved into the two forces, having the directions and velocities represented by the sides. This practice is of the most extensive and multifarious use in all mechanical disquisitions. It may frequently be exceedingly difficult to manage the complication of the many real forces which concur in producing a phenomenon; and by substituting others, whose combined effects are equivalent, our investigation may be much expedited. But more of this afterwards.

We must carefully remember, that when the motion AD is once begun, all composition is at an end, and the motion is a simple motion. The two determinations, by one of which the body would describe AB, and by the other of which it would describe AC, no longer co-exist in the body. This was the case only in the instant, in the very act of changing the motion AB into the motion BD; yet is the motion AD equivalent to a motion which is produced by the actual composition of two motions AB and AC; in which case the two motions co-exist in every point of AD.

47. *Usual demonstration inconclusive.* Accordingly this is the way in which the composition of forces is usually illustrated, and thought to be demonstrated. A man is supposed (for instance) to walk uniformly from A to C on a sheet of ice, while the ice is carried uniformly along AB by the stream. The man's real motion is undoubtedly along AD; but this is by no means a demonstration that the instantaneous or short-lived action of two forces would produce that motion; the man must continue to exert force in order to walk, and the ice is dragged along by the stream. Some indeed express this proof in another way, saying, let a body describe AB, while the space in which this motion is performed is carried along AC.

The ice may be carried along, and may, by friction, or otherwise, drag the man along with it; but a space cannot be removed from one place to another, nor, if it could, would it take the man with it. Should a ship start suddenly forward while a man is walking across the deck, he would be left behind, and fall toward the stern. We must suppose a transverse force, and we must suppose the composition of this force without proof. This is no demonstration.

We apprehend that the demonstration given above of this fundamental proposition is unexceptionable, when the terms force and deflection are used in the abstract sense which we have affixed to them; and we hope, by these means, to maintain the rigour of mathematical discussion in all our future disquisitions on these subjects. The only circumstance in it which can be the subject of discussion is, whether we have selected the proper measure and characteristic of a change of motion.—We never met with any objection to it.

But some have still maintained, that it does not evidently appear, from these principles, that the motion which results from the joint action of two natural powers, whose known and measurable intensities have the same proportions with AB and BC, and which also exert themselves in those directions, will produce a motion, having the direction and proportion of AD. They will not, if the velocities produced by these forces are not in the proportion of those intensities, but in the subduplicate ratio of them. Nay, they say, that it is not so. If a body be impelled along AC by one spring, and along AB by two springs equally strong, it will not describe the diagonal of a parallelogram, of which the side AB is double the side AC. Nay, they add, that an indefinite number of examples can be given where a body does not describe the diagonal of the parallelogram by the joint action of two forces, which, separately, would cause it to describe the sides. And, lastly, they say that, at any rate, it does not appear evident to the mind, that two incitements to motion, having the directions and the same proportion of intensity with that of the sides of a parallelogram, actually generate a third, which is the immediate cause of the motion in the diagonal. An equivalent force is not the same with a resulting force.

Yet we see numberless cases of the composition of incitements to motion, and they seem as determinate, and as susceptible of being combined by composition, as the things called moving forces, which are measured by the velocities: we see them actually so combined in a thousand instances, as in the example already given of a lighter dragged by two horses pulling in different directions. Nay, experiment shews, that this composition follows precisely the same rule as the composition of the forces which are measured by the velocities; for if the point A (fig. 1.) be pulled by a thread, or pressed by a spring, in the direction AB, and by another in the direction AC, and if the pressures are proportional to AB and AC, then it will be withheld from moving, if it be pulled or pressed by a third force, acting in the direction Ad, opposite to AD, the pressure being also proportional to AD. This force, acting in the direction Ad, would certainly withstand an equal force acting in the direction AD; therefore we must conclude, that the two pressures AB and AC really generate a force AD. This uniform agreement shews

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43. *Objections to the demonstration of n^o 45.* It will not apply to pressures.

49.

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that the composition is deducible from fixed principles; but it does not appear that it can be held as demonstrated by the arguments employed in the case of motions. A demonstration of the composition of pressures is still wanted, in order to render mechanics a demonstrative science.

This composition is of more difficult investigation.

Accordingly, philosophers of the first eminence have turned their attention to this problem. It is by no means easy; being so nearly allied to first principles, that it must be difficult to find axioms of greater simplicity by which it may be proved.

Mechanicians generally contented themselves with the solution given by Aristotle; but this is merely a composition of motions: indeed he does not give it for any thing else, and calls it "συνθεσις των δυων." The first writer who appears to have considered it as different from the mere composition of motions, was the celebrated Dutch engineer Stevinus in his work on *Sluices*; but his solution is obscure. It was sufficient, however, to convince Daniel Bernoulli of the necessity and the difficulty of the problem. He has given the first complete demonstration of it in the first volume of the Commentaries of the Imperial Academy of Sciences at St Petersburg. It is extremely ingenious; but it is tedious and intricate, requiring a series of 15 propositions to demonstrate that two pressures, having the directions and magnitudes of the sides of any parallelogram, compose a third, which has the direction and magnitude of its diagonal. His first proposition is, that *two equal pressures, acting at right angles, compose a third, in the direction of the diagonal of a square, and having to either of the other two the proportion of the diagonal of a square to its sides.*

Mr D'Alembert has greatly simplified and improved this demonstration, by beginning with a case that is self-evident; namely, *If three equal forces are inclined to each other in equal angles of 120 degrees, any one of them will balance the combined action of the other two.* Surely; for neither of them can prevail. Therefore two equal forces, inclined in an angle of 120 degrees, produce a third, which has the direction and proportion of the diagonal of the rhombus; for this is equal and opposite to one of the three above mentioned. He then demonstrates the same thing of two equal forces inclined in any angle; and by a series of eight propositions more, demonstrates the general theorem. This dissertation is in the Memoirs of the Academy at Paris for 1769. He improves it still farther in a subsequent memoir.

Mr Riccati and Mr Fonfenex, in the Commentaries of the Academy of Turin, have given analytical demonstrations, which are also very ingenious and concise, but require acquaintance with the higher mathematics.— There is another very ingenious demonstration in the *Journal des Sçavans* for June 1764, but too obscure for an elementary proposition. It is somewhat simplified by Belidor in his *Ingenieur François*. Frisius, in his *Cosmographia*, has given one, which is perhaps the best of all those that are easily comprehended without acquaintance with the higher mathematics: but we imagine that, although no one can doubt of the conclusion, it has not that intuitive evidence for every step of the process that seems necessary.

50 Composition of pressures

We here offer another, composed by blending together the methods of Bernoulli and D'Alembert; and we imagine that no objection can be made to any step

of it. We limit it entirely to pressures, and do not at all consider nor employ the motions which they may be supposed to produce.

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(A) If two equal and opposite pressures or incitements to motion act at once on a material particle, it suffers no change of motion; for if it yields in either direction by their joint action, one of the pressures prevails, and they are not equal.

Equal and opposite pressures are said to BALANCE each other; and such as balance must be esteemed equal and opposite.

(B) If a and b are two magnitudes of the same kind, proportional to the intensities of two pressures which act in the same direction, then the magnitude $a + b$ will measure the intensity of the pressure, which is equivalent, and may be called equal, to the combined effort of the other two; for when we try to form a notion of pressure as a measurable magnitude, distinct from motion or any other effect of it, we find nothing that we can measure it by but another pressure. Nor have we any notion of a double or triple pressure different from a pressure that is equivalent to the joint effort of two or three equal pressures. A pressure a is accounted triple of a pressure b , if it balances three pressures, each equal to b , acting together. Therefore, in all proportions which can be expressed by numbers, we must acknowledge the legitimacy of this measurement; and it would surely be affectation to omit those which the mathematicians call *incommensurable*.

In like manner, the magnitude $a - b$ must be acknowledged to measure that pressure which arises from the joint action of two pressures a and b acting in opposite directions, of which a is the greatest.

(C) Let ABCD and $A'bC'd$ (fig. A) be two rhombuses, which have the common diagonal AC. Let the angles BA b , DA d , be bisected by the straight lines AE and AF.

If there be drawn from the points E and F the lines EG, EH, Fg, Fh, making equal angles on each side of EA and FA, and if Gg, Hh be drawn, cutting the diagonal AC in I and L: then AI + AL will be greater or less than AQ, the half of AC, according as the angles GEH, gFh, are greater or less than GAH, gA'h.

Draw GH, g'h, cutting AE, AF, in O and o, and draw Oo, cutting AC in K.

Because the angles AEG and EAG are respectively equal to AEH and EAH, and AE is common to both triangles, the sides AG, GE are respectively equal to AH, HE, and GH is perpendicular to AE, and is bisected in O; for the same reasons, g'h is bisected in o. Therefore the lines Gg, Oo, Hh, are parallel, and IL is bisected in K. Therefore AI + AL is equal to twice AK. Moreover, if the angle GEH be greater than GAH, AO is greater than EO, and AK is greater than KQ. Therefore AI + AL is greater than AQ; and if the angle GEH be less than GAH, AI + AL is less than AQ.

(D) Two equal pressures, acting in the directions AB and AC (fig. 2.), at right angles to each other, compose a pressure in the direction AD, which bisects the right angle; and its intensity is to the intensity of each of the constituent pressures as the diagonal of a square to one of the sides. It is evident that the direction of the pressure, generated by their joint action, will

Second Law of Motion. will bisect the angle formed by their directions; because no reason can be assigned for the direction inclining more to one side than to the other.

In the next place, since a force in the direction AD does, in fact, arise from the joint action of the equal pressures AB and AC, the pressure AB may be conceived as arising from the joint action of two equal forces similarly inclined and proportioned to it. Draw EAF perpendicular to AD. One of these forces must be directed along AD, and the other along AE. In like manner, the pressure AC may arise from the joint action of a pressure in the direction AD, and an equal pressure in the direction AF. It is also plain, that the pressures in the directions AE and AF, and the two pressures in the direction AD, must be all equal. And also, any one of them must have the same proportion to AB or to AC, that AB or AC has to the force in the direction AD, arising from their joint action.

Therefore, if it be said that AD does not measure the pressure arising from the joint action of AB and AC, let Ad, greater than AD, be its just measure, and make $Ad : AB = Ag : AB = Ae : Ae$. Then Ag and Ae have the same inclination and proportion to AB that AB and AC have to Ad. We determine, in like manner, two forces Af and Ag as constituents of AC.

Now Ad is equivalent to AB and AC, and AB is equivalent to Ae and Ag; and AC is equivalent to Af and Ag. Therefore Ad is equivalent to Ae, Af, Ag, and Ag. But (A) Ae and Af balance each other, or annihilate each other's effect; and there remain only the two forces or pressures Ag, Ag. Therefore (B) their measure is a magnitude equal to twice Ag. But if Ad be greater than the diagonal AD of the square, whose sides are AB and AC; then Ag must be less than AI, the side of the square whose diagonal is AB. But twice Ag is less than AD, and much less than Ad. Therefore the measure of the equivalent of AB and AC cannot be a line Ad greater than AD. In like manner, it cannot be a line Ad that is less than AD. Therefore it must be equal to AD, and the proposition is demonstrated.

(E) Cor. Two equal forces AB, AC, acting at right angles, will be balanced by a force AO, equal and opposite to AD, the diagonal of the square whose sides are AB and AC; for AO would balance AD, which is the equivalent of AB and AC.

(F) Let AECF (fig. 3.) be a rhombus, the acute angle of which EAF is half of a right angle. Two equal pressures, which have the directions and measures AE, AF, compose a pressure, having the direction and measure AC, which is the diagonal of the rhombus.

It is evident, in the first place, that the compound force has the direction AC, which bisects the angle EAF. If AC be not its just measure, let it be AP less than AC. Let ABCD be a square described on the same diagonal, and make $AP : AQ = AE : AO = AF : Ao$. Draw KOG, Kog perpendicular to AE, AF; draw GIg, OHo, EG, EK, Fg, FK, PF, and PE.

The angles CAB and FAE are equal, each being half of a right angle. Also the figures AEPF and AGEK are similar, because $AP : AQ = AE : AO$. Therefore $FA : AP = KA : AE$, and $EA : AP = GA : AE$. Therefore, in the same manner that the

forces AE, AF are affirmed to compose AP, the forces AG and AK may compose the force AE, and the forces Ag and AK may compose the force AF. Therefore (B) the force AP is equivalent to the four forces AG, AK, Ag, AK. But (D) AG and Ag are the sides of a square, whose diagonal is equal to twice AI: and the two forces AK, AK are equal to, or are measured by, twice AK. Therefore the four forces AG, AK, Ag, AK, are equivalent to $2 AI + 2 AK = 4 AH$.

But because AP was supposed less than AC, the angle FPE is greater than FAE, and GEK is greater than GAK, AO is greater than OE, and AH is greater than HQ, and 2 AH is greater than AQ; and therefore 4 AH is greater than AC, and much greater than AP. Therefore AP is not the just measure of the force composed of AE and AF.

In like manner, it is shewn, that AE and AF do not compose a force whose measure is greater than AC. It is therefore equal to AC; and the proposition is demonstrated.

(G) By the same process it may be demonstrated, that if BAD be half a right angle, and EAF be the fourth of a right angle, two forces AE, AF will compose a force measured by AC. And the process may be repeated for a rhombus whose acute angle is $\frac{1}{4}$ th, $\frac{1}{8}$ th, &c. of a right angle; that is, any portion of a right angle that is produced by continual bisection. Two forces, forming the sides of such a rhombus, compose a force measured by the diagonal.

(H) Let ABCD, Abcd (fig. 4.) be two rhombuses formed by two consecutive bisections of a right angle. Let AECF be another rhombus, whose sides AE and AF bisect the angles BAb and DA d.

The two forces AE, AF, compose a force AC.

Bisect AE and AF in O and o. Draw the perpendiculars GOH, goh, and the lines GIg, OKo, HLh, and the lines EG, EH, Fg, Fh.

It is evident, that AGEH and AgFh are rhombuses; because $AO = OE$, and $Ao = oF$. It is also plain, that since bAd is half of BAD, the angle GAH is half of bAd. It is therefore formed by a continual bisection of a right angle. Therefore (G) the forces AG, AH, compose a force AE; and Ag, Ah, compose the force AF. Therefore the forces AG, AH, Ag, Ah, acting together, are equivalent to the forces AE, AF acting together. But AG, Ag compose a force = 2 AI; and the forces AH, Ah compose a force = 2 AL. Therefore the four forces acting together are equivalent to $2 AI + 2 AL$, or to 4 AK. But because AO is $\frac{1}{2}$ AE, and the lines Gg, Oo, Hh, are evidently parallel, 4 AK is equal to 2 AQ, or to AC; and the proposition is demonstrated.

(I) Cor. Let us now suppose, that by continual bisection of a right angle we have obtained a very small angle a of a rhombus; and let us name the rhombus by the multiple of a which forms its acute angle.

The proposition (G) is true of a, 2a, 4a, &c. The proposition (H) is true of 3a. In like manner, because (G) is true of 4a and 8a, proposition (H) is true of 6a; and because it is true of 4a, 6a, and 8a, it is true of 5a and 7a. And so on continually till we have demonstrated it of every multiple of a that is less than a right angle.

(K) Let RAS (fig. 5.) be perpendicular to AC, and

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and let ABCD be a rhombus, whose acute angle BAD is some multiple of $2a$ that is less than a right angle. Let $A b c d$ be another rhombus, whose sides $A b, A d$ bisect the angles RAB, SAD. Then the forces $A b, A d$ compose a force AC.

Draw $b R, d S$ parallel to BA, DA. It is evident, that $AR b B$ and $AS d D$ are rhombuses, whose acute angles are multiples of a that are each less than a right angle. Therefore (I) the forces AR and AB compose the force $A b$, and AS, AD compose $A d$; but AR and AS annihilate each other's effect, and there remains only the forces AB, AD. Therefore $A b$ and $A d$ are equivalent to AB and AD, which compose the force AC; and the proposition is demonstrated.

(L) Cor. Thus is the corollary of last proposition extended to every rhombus, whose angle at A is some multiple of a less than two right angles. And since a may be taken less than any angle that can be named, the proposition may be considered as demonstrated of every rhombus: and we may say,

(M) Two equal forces, inclined to each other in any angle, compose a force which is measured by the diagonal of the rhombus, whose sides are the measures of the constituent forces.

(N) Two forces AB, AC (fig. 6.), having the direction and proportion of the sides of a rectangle, compose a force AD, having the direction and proportion of the diagonal.

Draw the other diagonal CB, and draw EAF parallel to it; draw BE, CF parallel to DA.

AEBG is a rhombus; and therefore the forces AE and AG compose the force AB. AFCG is also a rhombus, and the force AC is equivalent to AF and AG. Therefore the forces AB and AC, acting together, are equivalent to the forces AE, AF, AG, and AG acting together, or to AE, AF, and AD acting together: But AE and AF annihilate each other's action, being opposite and equal (for each is equal to the half of BC). Therefore AB and AC acting together, are equivalent to AD, or compose the force AD.

(O) Two forces, which have the direction and proportions of AB, AC (fig. 7.) the sides of any parallelogram, compose a force, having the direction and proportion of the diagonal AD.

Draw AF perpendicular to BD, and BG and DE perpendicular to AC.

Then AFBG is a rectangle, as is also AFDE; and AG is equal to CE. Therefore (N) AB is equivalent to AF and AG. Therefore AB and AC acting together, are equivalent to AF, AG, and AC acting together; that is, to AF and AE acting together; that is (N) to AD; or the forces AB and AC compose the force AD.

Hence arises the most general proposition,

51
Composition
of incitements
to motion.

If a material particle be urged at once by two pressures or incitements to motion, whose intensities are proportional to the sides of any parallelogram, and which act in the directions of those sides, it is affected in the same manner as if it were acted on by a single force, whose intensity is measured by the diagonal of the parallelogram, and which acts in its direction: Or, two pressures, having the direction and proportion of the sides of a parallelogram, generate a pressure, having the direction and proportion of the diagonal.

Thus have we endeavoured to demonstrate from abstract principles the perfect similarity of the composition

of pressures, and the composition of forces measured by the motions which they produce. We cannot help being of the opinion, that a separate demonstration is indispensably necessary. What may be fairly deduced from the one case, cannot always be applied to the other. No composition of pressures can explain the change produced by a defecting force on a motion already existing; for the changing pressure is the only one that exists, and there is none to be compounded with it. And, on the other hand, our notions and observations of the composition of motions will not explain the composition of pressures, unless we take it for granted that the pressures are proportional to the velocities; but this is perhaps a gratuitous assumption. At any rate, it is not an intuitive proposition; and we have mentioned some facts where it seems that they do not follow the same proportion. The pressure of four equal springs produces only a double velocity. It would appear, therefore, that there are circumstances which oblige us to say, that the exertion of pressure, as a cause of motion, is not (always at least) proportional to the real measurable pressure. We are therefore anxious to discover in what the difference consists; and in the mean time must allow, that the pressure exerted on a body at rest is different from its exertion in producing motion. We cannot indeed state any immediate comparison between pressure and motion, nor have we any clear conception of the connection between them. It is only by our sensations of touch that we have any notion of pressure, and it is experience that teaches us that it always accompanies every cause of motion. We can, however, observe the proportions of pressures, and compare them with the proportions of motion. We very often observe them different; and therefore it was indispensably necessary to investigate the laws of combined pressure as we did the laws of combined motion in consequence of pressure. Yet we should err, if we hastily asserted that pressures are not proportional to the motions which they produce; all that we are intitled to call in doubt is, whether the pressures in their exertion, while they actually produce motion, or changes of motion, continue to be the same as when they do not produce motion, being withstood or balanced by opposite pressures. Considered as causes of motion, we ought to think that they do not vary while they produce motion, and that the actual pressure, while it produces a double motion, is really double, although it may be quadruple when the body exerting it is made to act on a body that it cannot move. We are confirmed in this opinion by observing, that other facts shew us, that even while producing motion, the pressure which we call quadruple, because we have measured it by four equal pressures balancing it, is really quadruple, considered as the cause of motion, and produces a quadruple motion. A bow which requires four times the force to draw it to any given extent, will communicate the same velocity to a bundle of four arrows that a bow four times easier drawn communicates to one arrow, and will therefore produce a quadruple motion. Yet it will only produce a double velocity in the arrow that acquired a simple velocity from a bow having one fourth of the strength.

These discrepancies should excite the endeavours of mechanicians to investigate the laws observed in the action of pressures in producing motion. Had this been done with care and with candour, we should not have

had

Second Law of Motion. had the great difference of opinion, which still divides philosophers, about the measures of moving forces. But a spirit of party, which had arisen from other causes, gave importance to what was at first only a difference of expression, and made the partisans of Mr Leibnitz avail themselves of the figurative language which has done so much harm in all the departments of philosophy. Notwithstanding all our caution, it is hardly possible to avoid metaphorical conceptions when we employ the language of metaphor. The abettors of the Leibnitzian measure of moving forces, or perhaps, to speak more properly, the abettors of the Leibnitzian measure of that force which is supposed to preserve bodies in their condition of motion—infirm, that the force which is exerted in producing any change of motion is greater in proportion as the motion changed is greater: and they give a very specious argument for their assertion. They appeal to the exertions which we ourselves make. Here we are conscious of the fact. Then they give similar examples of the action of bodies. A clay ball, moving six feet per second, will make the addition of one foot to the velocity of an equal clay ball that is already moving four feet per second in the same direction. But if this last ball be already moving ten feet per second, we must follow it with a velocity of twelve feet in order to increase its velocity one foot. But, without insisting on the numberless paralogisms and inconsistencies which this way of conceiving the matter would lead us into, it suffices to observe, that the phenomena give us abundant assurance that there has been the same exertion in both these cases. This acceleration is always accompanied by a compression of the balls, and the compression is the same in both. This compression is a very good measure of the force employed to produce it; and in the present case, we need not even trouble ourselves with any rule for its measurement: for surely when the compression is not different, but the same, the force exerted is the same. This is farther confirmed by observing, that it requires the same force to make the same pit, or to give the same motion, to a piece of clay lying on the table of a ship's cabin, whether the ship be sailing two miles or ten miles per hour.

Thus we see that there are strong reasons for believing, that the exertions of pressure in producing motion, or that the pressures *actually exerted*, are proportional to the changes of motion observed, and that they coincide in this respect with our abstract conceptions of moving forces.

But we have still better arguments. None of the Leibnitzians think of denying the equal exertions of gravity, or of any of those powers which they call *solicitations* or *accelerating forces*. They all admit, that gravity, or any constant accelerating force, produces equal increments of velocity in equal times, and that a double gravity will produce a double increment in an equal time, and an equal increment in half of the time; and that a quadruple gravity will produce a double velocity in half the time. All these things are granted by them, and their writings are full of reasonings from this principle. Now from the fact, acknowledged by the Leibnitzians, that the quadruple force of a bow gives a double velocity to the arrow, in every instant of its action, it indisputably follows, that it has acted on it only for half the time of the action of the four

times weaker bow, which gives the arrow only half the velocity; and thus has the discrepancy between the effects of pressures and of our abstract moving forces entirely disappeared. For this circumstance of the difference in the time of acting will be found, on strict examination, in all the cases of the change of motion by pressures which we measure by their effects on a body at rest. When this and the appreciable changes of actual pressure, during the time of producing the motion, are taken into consideration, all difference vanishes, and the composition of pressures is in perfect harmony with the composition of motions, or of abstract moving forces. DYNAMICS is thus made a demonstrative science, and affords the opportunity of investigating, by observation and experiment, the nature of those mechanical powers which reside in bodies, and which appear to us under the form of pressure, inducing us to consider pressure as a cause of motion.

In this, however, we are rather inaccurate. Pressure is one of the sensible effects of that property which is also the cause of motion. It is not the pressure of a piece of lead, but its heaviness, that is the reason that it gives motion to a kitchen jack. Pressure is merely a generic name, borrowed from a familiar instance, and given to moving forces, which have the same nature, but different names that serve to mark their connection with certain substances, in which they may be supposed to reside. Natural philosophy is almost entirely employed in examining the nature of these various pressures or accelerative forces; and the general doctrines of dynamics, by ascertaining what is common to them all, enable us to mark with precision what is characteristic of each.

We have now advanced very far in this investigation; for we have obtained the criterion by which we learn the direction and the magnitude of every changing force: and, on the other hand, we see how to state what will be the effect of the exertion of any force that is known or suspected to act. All this we learn by the composition of forces; and the greatest part of mechanical disquisition consists in the application of this doctrine. For such reasons it merits minute consideration; and therefore we must point out some general conclusions from the properties of figure, which will greatly facilitate the use of the parallelogram of forces.

1. The constituent and the resulting forces, or the simple and compound forces, act in the same plane; for the sides and diagonal of a parallelogram are in one plane.

2. The simple and the compound forces are proportionally to the sides of any triangle which are parallel to their directions. For if any three lines, *ab*, *bd*, *ad*, be drawn parallel to *AB*, *AC*, and *AD* (fig. 7, 11^o 2.), they will form a triangle similar to the triangle *ABD*. For the same reasons they are proportional to the sides of a triangle *abd*, which are respectively perpendicular to their directions.

3. Therefore each is proportional to the sine of the opposite angle of this triangle; for the sides of any triangle are proportional to the sines of the opposite angles.

4. Each is proportional to the sine of the angle contained by the directions of the other two; for *AD* is to *AB* as the sine of the angle *ABD* to the sine of the angle *ADB*. Now the sine of *ABD* is the same

with

Second Law of Motion.

53. General considerations.

54.

55.

56.

57.

Second Law of Motion.

with the line of BAC contained between the directions AB and AC, and the line of ADB is the same with the line of CAD; also AB is to AC, or BD, as the line of ADB (or CAD) to the line of BAD.

58 Some special uses of the parallelogram of forces.

We now proceed to the application of this fundamental proposition. And we observe, in the first place, that since AD may be the diagonal of an indefinite number of parallelograms, the motion or the pressure AD may result from the joint action of many pairs of forces. It may be produced by forces which would separately produce the motions AF and AG. This generally gives us the means of discovering the forces which concur in its production. If one of them, AB, is known in direction and intensity, the direction AC, parallel to BD, and the intensity, are discovered. Sometimes we know the directions of both. Then, by drawing the parallelogram or triangle, we learn their proportions. The force which deflects any motion AB into a motion AD, is had by simply drawing a line from the point B (to which the body would have moved from A in the time of really moving from A to D) to the point D. The deflecting force is such as would have caused the body move from B to D in the same time. And, in the same manner, we get the compound motion AD, which arises from any two simple motions AB and AC, by supposing both of the motions to be accomplished in succession. The final place of the body is the same, whether it moves along AD or along AB and BD in succession.

59 Equivalent of many forces.

This theorem is not limited to the composition of two motions or two forces only; for since the combined action of two forces puts the body into the same state as if their equivalent alone had acted on it, we may suppose this to have been the case, and then the action of a third force will produce a change on this equivalent motion. The resulting motion will be the same as if only this third force and the equivalent of the other two had acted on the body. Thus, in fig. 8. the three forces AB, AC, AE, may act at once on a particle of matter. Complete the parallelogram ABDC; the diagonal AD is the force which is generated by AB and AC. Complete the parallelogram AEFD; the diagonal AF is the force resulting from the combined action of the forces AB, AC, and AE. In like manner, completing the parallelogram AGHF, the diagonal AH is the force resulting from the combined action of AB, AC, AE, and AG, and so on of any number of forces.

Plate XXII.

This resulting force and the resulting motion may be much more expeditiously determined, in any degree of composition, by drawing lines in the proportion and direction of the forces in succession, each from the end of the preceding. Thus, draw AB, BD, DF, FH, and join AH; AH is the resulting force. The demonstration is evident.

60

It is to be noticed here, that in the composition of more than two forces, we are not limited to one plane. The force AD is in the same plane with AB and AC; but AE may be elevated above this plane, and AG may lead below it. AF is in the plane of AD and AE, and AH is in the plane of AF and AG.

Complete the parallelograms ABLE, ACKE, ELFK. It is evident that ABLFKD is a parallelepiped, and that AF is one of its diagonals. Hence we derive a more general theorem of great use.

Three forces having the proportion and direction of the three sides of a parallelepiped, compose a force having the proportion and direction of the diagonal.

Second Law of Motion

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Any number of forces acting together on one particle of matter are balanced by a force that is equal and opposite to their resulting force; for this force would balance their resulting force which is equivalent to them in action. When this is duly considered, we perceive that each force is then in equilibrio with the equivalent of all the others; for a force can balance only what is equal and opposite to it. It appears very readily by the geometrical construction. If, instead of the circuit A, B, D, F, H, we take B, D, F, H, A, we have BA for the equivalent of the forces AC, AE, AG; but AB is equal and opposite to BA. Therefore the force AB is in equilibrio with the equivalent of all the others.

One force may balance many acting together.

62.

When any number of forces act on one particle of matter, and are in equilibrio, if they be considered as acting in parcels, the equivalents of these parcels are in equilibrio; for let the forces AB, AC, AE, AG, Ab, be in equilibrio, and let them be considered in the two parcels AB, AC, and AE, AG, Ab; then AD is the equivalent of AB, BD (or AC), and DA is the equivalent of DF, FH, HA (or Ab): now AD and DA balance each other. This corollary enables us to simplify many intricate complications of force; it also enables us to draw accurate conclusions from very imperfect observations. In most of our practical discussions we know, or at least we attend to, a part only of the forces which are acting on a material particle; and in such cases we reason as if we saw the whole: yet is our mathematical reasoning good with respect to the equivalent of all the parcels which we are contemplating, and the equivalents of the smaller parcels of which it consists; and the neglected force, or parcel of forces, induces no error on our conclusions.

63.

In the spontaneous phenomena of nature, the investigation and discovery of our ultimate object of search is frequently very difficult, on account of the multiplicity of directions and intensities of the operating forces or motions. We may generally facilitate the process, by substituting equivalent forces or motions acting in convenient directions. It is in this way that the navigator computes the ship's place with very little trouble, by substituting equivalent motions in the meridional and equatorial directions for the real oblique courses of the ship. Instead of setting down ten miles on a course, S. 36. 52. W. he supposes that the ship has sailed eight miles due south, and six miles due west, which brings her near to the same place. Then, instead of fourteen miles south-west, he sets down ten miles south and ten miles west; and he proceeds in the same way for every other course and distance. He does this expeditiously by means of a traverse table, in which are ready calculated the meridional and equatorial sides of right angled triangles, corresponding to every course and distance. Having done this for the course of a whole day, he adds all the southings into one sum and all the westings into another: he considers these as forming the sides of a right angled triangle; he looks for them, paired together, in his traverse table, and then notices what angle and what distance corresponds to this pair. This gives him the position and magnitude of the straight line joining the beginning and end of his day's work.

Expedition methods for obtaining the resulting motion in complicated cases.

Second Law of Motion.

Second Law of Motion.

The miner proceeds in the same way when he takes the plan of subterraneous workings, measuring, as he goes along, and noticing the bearing of each line by the compass, and setting down, from his traverse table, the northing or southing, and the easting or westing, for each oblique line: but there is another circumstance which he must attend to, namely, the slope of the various drifts, galleries, and other workings. This he does by noting the rise or the dip of each stoning line. He adds all these into two sums; and taking the risings from the dips, he obtains the whole dip. Thus he learns how far the workings proceed to the north, how far to the east, and how far to the dip.

The reflecting reader will perceive that the line joining the two extremities of this progression will form the diagonal of a rectangular parallelopiped; one of whose sides lies north and south, the other lies east and west, and the third is right up and down.

The mechanician proceeds in the very same way in the investigation of the very complicated phenomena which frequently engage his attention. He considers every motion as compounded of three motions in some convenient directions, at right angles to each other. He also considers every force as resulting from the joint action of three forces, at right angles to each other, and takes the sum or difference of these in the same or opposite directions. From this process he obtains the three sides of a parallelopiped; and from these computes the position and magnitude of the diagonal. This is the motion or force resulting from the composition of all the partial ones.

This procedure is called the ESTIMATION or REDUCTION of motions and forces.

A motion or force AB (fig. 9.) is said to be *estimated* in the direction EF, or to be *reduced* to this direction when it is conceived as compounded of the motions or forces AC, AD, one of which AC is parallel to EF, and the other AD is perpendicular to it. This expression is abundantly significant; for it is plain that the motion AD neither promotes nor hinders the progress along EF, and that AC expresses the whole progress in this direction.

In like manner, a force AB (fig. 10.) is said to be *estimated in*, or *reduced to*, a given plane EFGH, when it is conceived as resulting from the joint action of two forces AC, AD, one of which is parallel to a line *ab* drawn in that plane, and the other AD is perpendicular to it. The position of the line *ab* is determined by letting fall B *b* perpendicular to the plane, and drawing *bP* to the point P, in which BA meets the plane; then A *a* being drawn parallel to B *b*, will cut off *ba*, which is the reduction of the motion AB to the plane. Drawing C parallel to *ab*, and completing the parallelogram ACBD, it is evident that the motion AB is equivalent to AD and AC, which is parallel to *ab*, and the three forces AB, AC, AD, are, as they should be, in one plane perpendicular to the plane EG.

If three forces AB, AC, AD (fig. 11.), are in equilibrio, and are reduced to any one direction *dAl*, or to one plane EFGH, the reduced forces are also in equilibrio.

First, Let them be reduced to one direction *dl* by drawing the perpendiculars B *b*, C *c*, D *d*; make AL equal to AD, and join BL, CL, and draw the perpendiculars L *l*, C *c*; then, because the forces AB, AC,

AD, are in equilibrio, ABLC must be a parallelogram, and AL is the force equivalent to AB and AC combined; then, because the lines D *d*, B *b*, C *c*, L *l*, are parallel, *dA* is equal to A *l*, and A *b* to C *c*, or to *cl*; therefore AL is equal to the sum of A *b* and A *c*, which are the reductions of AB and AC; therefore *dA* is equal to the same sum, and in equilibrio with them.

Secondly, Let them be reduced to one plane EFGH, and let $\alpha\beta, \alpha\kappa, \alpha\delta$, be the reduced forces. The lines D *s*, A *a*, B *\beta*, C *\kappa*, L *\lambda*, are all parallel, being perpendicular to the plane; therefore the planes AB *\beta a* and CL *\lambda c* are parallel, and $\alpha\beta, \alpha\kappa$, are parallel. For similar reasons $\beta\lambda, \alpha\kappa$, are parallel; therefore $\alpha\beta\lambda\kappa$ is a parallelogram. Also, because the lines D *s*, A *a*, L *\lambda*, are parallel, and DA is equal to AL; therefore *sa* is equal to $\alpha\lambda$. But because $\alpha\beta\lambda\kappa$ is a parallelogram, the forces $\alpha\beta, \alpha\kappa$, are equivalent to $\alpha\lambda$; and αs is equal and opposite to $\alpha\lambda$, and will balance it; and therefore will balance $\alpha\beta$ and $\alpha\kappa$, which are the reductions of AB and AC to the plane EFGH, while αs is the reduction of AD; therefore the proposition is demonstrated.

The most usual and the most useful mode of reduction is to estimate all forces in the directions of three lines drawn from one point, at right angles to each other, like the three plane angles of a rectangular chest, forming the length, the breadth, and the depth of the chest. These are commonly called the three coordinates. The resulting force will be the diagonal of this parallelopiped. This process occurs in all disquisitions in which the mutual action of solids and fluids is considered, and when the oscillation or rotation of detached free bodies is the subject of discussion.

The only other general theorem that remains to be deduced from this law of motion is, that if a number of bodies are moving in any manner whatever, and an equal force act on every particle of matter in the same or parallel directions, their relative motions will suffer no change; for the motion of any body A (fig. 12.), relative to another body B, which is also in motion, compounded of the real motion of A, and the opposite to the real motion of B; for let A move uniformly from A to C, while B describes BD uniformly, draw AB, also draw AE equal and parallel to BD, join EC, DC, ED. The motion of A, relative to B, consists in its change of position and distance. Had A described AE, while B described BD, there would have been no change of relative place or distance; but A is now at C, and DC is its new direction and distance. The relative or apparent motion of A therefore is EC. Complete the parallelogram ACFE; it is plain that the motion EC is compounded of EF, which is equal and parallel to AC, the real motion of A, and of EA, the equal and opposite to BD, the real motion of B.

Now let the motions of A and B sustain the same change; let the equal and parallel motions AG, BH, be compounded with the motions AC and BD; or let forces act at once on A and B, in the parallel directions AG, BH, and with equal intensities; in either supposition, the resulting motions will be A *c*, B *d*. the diagonals of the parallelograms A G *c* C, and B H *d* D. Construct the figure as before, and we see that the relative motion is now *ec*, and that it is the same with EC both in respect of magnitude and position.

Here we still see the constant analogy between the composition of motions and the composition of forces.

Forces may be estimated by, or reduced to, a given direction.

65 Or a given plane.

66 Equilibrium of forces so estimated or reduced.

67 Relative motions of bodies not affected by any extraneous equal and parallel force.

Second Law of Motion.

In the first case, the relative motions of things are not changed, whatever common motion be compounded with them all; or, as it is usually, but inaccurately, expressed, although the space in which they move be carried along with any motion whatever. In the second case, the relative motions and actions are not changed by any external force, however great, when equally exerted on every particle in parallel directions.

Thus it is that the evolutions of a fleet in a uniform current are the same, and produced by the same means, as in still water. Thus it is that we walk about on the surface of this globe in the same manner as if it neither revolved round the sun, nor turned round its axis. Thus it is that the same strength of a bow will communicate a certain velocity to an arrow, whether it is shot east, or west, or north, or south. Thus it is that the mutual actions of sublunary bodies are the same, in whatever directions they are exerted, and notwithstanding the very great changes in their velocities by reason of the earth's rotation and orbital revolution. The real velocity of a body on the earth's equator is about 3000 feet per second greater at midnight than at midday. For at midnight the motion of rotation nearly conspires with the orbital motion, and at midday it nearly opposes it. The difference between the velocities at the beginning of January and the beginning of July is vastly greater. And at other times of the day, and other seasons of the year, both motions of the earth are transversely compounded with the easterly or westerly motion of an arrow or cannon bullet. Yet we can observe no change in the effects of the mutual actions of bodies.

tem, are counterparts of each other. Since this independence is a matter of observation in all terrestrial bodies, we are intitled to say, that the powers which the Author of Nature has imparted to natural bodies are no way different from what are competent to matter once called into existence. And it also follows from this, that we must always remain ignorant of the absolute motions of bodies. The fact, that it has required the unremitted study of ages to discover even the relative motions of our solar system, is an argument to prove that the influence of this mechanical principle extends far beyond the limits of this sublunary world; nor has any phenomenon yet been exhibited which should lead us to imagine that it is not universal.

Second Law of Motion.

When we have made use of these arguments with some zealous partizans of Mr Leibnitz's doctrine, they have answered, that if indeed this independence of the relative motions of terrestrial bodies were observed to obtain exactly, it would be a conclusive argument. But the motion with which all is carried along is so great in comparison with the motions which we can produce in our experiments, that the small additions or diminutions that we can make to the velocity of this common motion must observe very nearly the proportions of the additions or diminutions of their squares. The differences of the squares of 2, 3, and 4, are very unequal; but the differences of the squares of 9, 10, 11, are much nearer to the ratio of equality; and the differences of the squares of 1000001, 1000002, 1000003, do not sensibly deviate from this ratio. But it is not fact that we cannot produce motions which have a very sensible proportion to the common motion. The motion of a cannon ball, discharged with one third of its weight of powder, is nearly equal to that of the rotation of the earth's equator. When, therefore, we discharge the ball eastward, we double its motion; when to the westward, we destroy it. Therefore, according to Leibnitz, the action in the first case is three times the action in the second. In the first case it changes the square of the velocity (which we may call 1) from 1 to 4; and, in the second, it changes it from 1 to 0. But say the Leibnitzians, the velocity of rotation is but $\frac{1}{31\frac{1}{2}}$ of the orbital velocity of the earth, and our observations of the velocities of cannon bullets are not sufficiently exact to ensure us against an error of $\frac{1}{31\frac{1}{2}}$. But

So Bernoulli's defence of this last opinion is without force.

68 This affords a demonstration of the proportionality of moving forces to the motions produced by them,

This is an important observation; because it proves that forces are to be measured by no other scale than by the motions which they produce. We have had repeated occasions to mention the very different estimation of moving forces by Mr Leibnitz; and have shewn how, by a very partial consideration of the action of those natural powers called *pressures*, he has attempted to prove that moving forces are proportional to the squares of the velocities; and we shewed briefly, in what manner a right consideration of what passes when motion is produced by measurable pressures, proves that the forces really exerted are as the velocities produced. But the most copious proof is had from the present observation, that, in fact, the mutual actions of bodies depend on their relative motions alone.

69 And is incompatible with their proportionality to the squares of those motions.

The Leibnitzian measure of moving force is altogether incompatible with the universal fact now mentioned, *viz.* that the relative motions of bodies, resulting from their mutual actions, are not affected by any common motion, or the action of any equal and parallel force on both bodies: for this universal fact imports, that when two bodies are moving with equal velocities in the same direction, a force applied to one of them, so as to increase its velocity, gives it the same motion relative to the other, as if both bodies had been at rest. Here it is plain that the space described by the body in consequence of the primitive force, and of the force now added, is the sum of the spaces which each of them would generate in a body at rest. Therefore the forces are proportional to the velocities or changes of motion which they produce, and not to the squares of those velocities. This measure of forces, or the position that a force makes the same change on any velocity whatever, and the dependence of the relative motions on any motion that is the same on all the bodies of a sys-

tem, are counterparts of each other. Since this independence is a matter of observation in all terrestrial bodies, we are intitled to say, that the powers which the Author of Nature has imparted to natural bodies are no way different from what are competent to matter once called into existence. And it also follows from this, that we must always remain ignorant of the absolute motions of bodies. The fact, that it has required the unremitted study of ages to discover even the relative motions of our solar system, is an argument to prove that the influence of this mechanical principle extends far beyond the limits of this sublunary world; nor has any phenomenon yet been exhibited which should lead us to imagine that it is not universal.

the later observations on the peculiar motions of the fixed stars concur in shewing, that the sun, with his attending planets, are carried along with a very great motion, which, in all probability, has a sensible ratio to the orbital motion of the earth. This must make a prodigious change on the earth's absolute motion, according as her orbital motion conspires with, opposes, or crosses, this other motion: the earth may even be at absolute rest in some points of its orbit. Thus will the composition with the motions produced in our experiments be so varied, that cases *must* occur when the difference of the results of the two measures of force will be very sensible.

But, farther, they have not attended to the agreement of our experiments, when the discharges of cannon are made in a direction transverse to that of the common motion. Here the immensity of the common motion, and the minuteness of our experimental velocities, can have no effect in diminishing the difference of the results of the two doctrines. This will appear distinctly

mentations of this train are not the causes of our conclusions, but the means by which we form our judgement; not the reasons of the truth of our ultimate conclusion, but the steps by which we arrive at the knowledge of it. The young geometer generally thinks otherwise: But that this is the matter of fact is plain from this, that more than one demonstration, and often very different, can be given of the same theorem. We must proceed in the same manner in the present question; and the first general truths which we find involved in the notions of matter, motion, and force, must be received as *necessary* truths. The steps by which we arrive at the discovery are the laws of human thought; and the expression of the discovery, involving both the truth itself and the manner of conceiving it, is a necessary law of motion. There may be other facts, perhaps as general as any of those necessary laws, but which do not necessarily result from the relations of our notions of motion and of force. These are discovered by observation only; and they serve to characterise the forces which nature presents to our view. These facts are *contingent* laws of motion.

We apprehend that this method has been followed in treating this article. The first proposition, termed a *law of motion*, is only a more convenient way of expressing our contemplation of motion in body as an effect of the general cause which we term *force*. The second proposition does nothing but expresses distinctly the relation between this cause and its effect; it expresses what we mean by the magnitude and the kind of the cause. The proposition, stating the composition of forces, is but another form of the same law, better suited to the ordinary procedure in geometrical disquisitions.

THESE propositions might have completed the doctrines of dynamics; but it appears that, in order to the production of a material universe which should accomplish the purposes of the Creator, it was necessary that there be certain characteristic differences between the forces inherent in the various collections of matter which compose this universe. The facts or physical laws (for the above-mentioned laws are metaphysical) of motion may be different from those which would have been observed had matter been left entirely to itself. This difference may have introduced other laws of motion as necessarily resulting from the nature of the forces. We have occasionally mentioned some instances where this appears to obtain, but gave good reasons for affirming, that a due examination of all circumstances which may be observed in the production or variation of motion by those forces, has demonstrated that there are no such deviations from the two laws of motion already determined, but that all the mechanical powers of bodies, when considered merely as causes of motion, act agreeably to the same laws. Careful examination was, however, said to be necessary.

This examination must consist in distinctly noticing the circumstances that occur in the production of motion by any force whatever. It is by no means enough to state simply the intensity of the force and the direction of its exertion. If a force continue to act, it continues to vary the motion already produced. Should the force change its intensity or direction while it is acting, these circumstances must induce still farther

changes in the motion; and it is not till all action has ceased that the motion is brought to its ostensible state, in which it is the object of our attention and our future disquisitions. Instances of the effects of such continued and such varied actions are to be seen in most of the phenomena of nature or art. The communication of motion by impulse is perhaps the only instance (very frequent indeed) that can be produced where this is not necessary: Nay, we shall perhaps find reason to conclude, that this instance is not an exception, and that even the communication of motion from one billiard ball to another is brought about by an action continued for some time, and greatly varied during that time. Much preparation is therefore necessary before we can apply the general laws of motion to the solution of most of the questions which come before us in the course even of our elementary disquisitions. We must lay down some general propositions which determine the results of the continued, and perhaps varied, actions of moving forces; and we must mark the different effects of the simple continuation of action, and also those of the variations in this continued action, both in respect of intensity and direction. The effect of a mere continuance of action must be an acceleration of the motion; or a retardation of it, if the force continue to act in the opposite direction. The effect of the continued action of a transverse force must be a continual deflection, that is, a curvilinear motion. These must therefore now occupy our attention in their order.

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ALL men can perceive, that a stone dropped from the hand, or sliding down a uniform slope, has its motion continually accelerated, and that the motion of an arrow rising perpendicularly through the air is continually retarded; and they feel no difficulty in conceiving these changes of motion as the effects of the continual operation of their weight or heaviness. The falling stone is in a different condition in respect of motion in the beginning and the end of its fall. In what respect do these states of the body differ? Only in respect to what we call its *velocity*. This is an affection of motion; it is an expression of the relation between the two notions or ideas which concur to form the idea of motion; namely, the space and the time. These are all the circumstances that we observe in a motion. Time elapses, and during its currency a space is described. The term *velocity* expresses the magnitude of the space which corresponds to some unit of time. Thus, the rate of a ship's motion is determined, when we say that it is nine miles in an hour, or nine miles per hour. We sometimes say (but awkwardly) "The motion is at the rate, or with the velocity, of a mile in three days." It is most conveniently expressed by a number of some given units of length, which completely make up the line described during this unit of time. But the mechanicians express it in a way more general by a fraction, of which the numerator is a number of inches, feet, yards, fathoms, or miles, and the denominator is the number of seconds, minutes, or hours, employed in moving along this line. This is a very proper expression; for when we speak of any velocity, and continue to reason from it, we conceive ourselves to speak of something that remains the same, in the different occasions of using the term. Now if the velocity be constant, it is indifferent

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how long the line may be; because the time of its description will be lengthened in the same proportion. Thus if 48 feet be described in 12 seconds, 36 feet will be described in 9 seconds, 16 feet will be described in 4 seconds, &c. Now $\frac{4}{12}$, $\frac{3}{9}$, and $\frac{1}{4}$, are fractions of equal value, being equal to $\frac{1}{3}$, or $\frac{1}{4}$, that is, to the velocity of 4 feet per second. The value of this fraction, or the quotient of the number of the units of length, divided by the number of units of time, is the number of those units of length described uniformly in one unit of time.

Magnitude of a velocity of which we have no actual measure.

But how shall we determine the velocity of any instant or in any point of a motion that is continually changing? Suppose that a body has fallen 144 feet, and that we would ascertain its velocity in that point of its fall, or the velocity which it has in passing through that point? In the next second the body falls 112 feet farther. This cannot be the measure of the velocity at the beginning of the fourth or the end of the third second. It is too great. The fall during the preceding second was 80 feet. This is too small. The mean of these

two, or $\frac{80+112}{2} = \frac{192}{2} = 96$, is probably more exact.

Due attention to the nature of this motion shews us, that 96 is the proper measure, or that the motion at that instant is at the rate of 96 feet per second. But it is peculiar to this kind of motion that the half sum of the spaces described in two succeeding equal moments is the measure of the velocity in the middle instant. Therefore this method will not generally give an accurate measure. Yet it is indispensably necessary to obtain some accurate measure; for it is in this particular alone that the state of the body differs from its similar state in another instant. The difference of place makes no distinction; for if a body continue its motion unchanged, its condition in every different instant of time, or point of space, is unchanged or the same. The change of place is not a change of motion, but is involved in the very conception of the continuation of the motion. The change of condition consists, therefore, in the change of velocity. Therefore the change of velocity is the only indication, and the only measure of the action (perhaps accumulated) of the changing force. It is therefore the chief object of our search; and accurate measures of velocity are absolutely necessary.

When the velocity changes continually, there can be no actual measure of it. In what then does the magnitude of a velocity consist, when there is no actual measure of it? It is a certain undescribable DETERMINATION; by which, if not changed, a certain space would be uniformly described in a given unit of time. Thus we know, that if, when a stone has fallen 16 feet, its motion be directed along a horizontal plane, without diminution, it will move on for ever at the rate of 32 feet per second. The space which would be thus described is not the velocity, but the measure of the velocity. But the proportions of those spaces, being the proportions of those measures, are the proportions of the velocities themselves. We may discover these proportions in the following manner:

Let ACG (fig. 13.) be a line described by a body with a motion anyhow continually, but gradually, varied; and let it be required to determine the proportion of the velocity in any point C to the velocity in any other point F .

AXIOM.—If A be to B in a ratio that is greater than any ratio less than that of C to D , but less than any ratio greater than that of C to D , then A is to B as C to D .

Take the straight line acg to represent the time of the body's motion along ACG , so that the points a, c, f, g , may represent the instants of time in which the body passes through the points A, C, F, G ; and the portions ac, cf, fg , of the line ag , may represent the times employed in describing the portions AC, CF, FG ; and therefore ac is to af as the time of describing AC to the time of describing AF .

Moreover, let bkn be a line so related to the straight line $acfg$, by the perpendicular ordinates ab, ck, fn, go , and the areas $ackb, afnb, agnb$, may be proportional to the portions AC, AF, AG , of the line described by the moving body; and let this relation be true with respect to every point B, D, E , &c. and the corresponding points b, d, e , &c.

Then it is affirmed, that the velocity in the point C is to the velocity in the point F as ck is to fn .

Let the equal lines bc, cd, ef, fg , represent equal moments of time, and let B, D, E, G , be the points through which the body is passing at the instants b, d, e, g . Then the areas $bikc, ckl d, emnf, fno g$, will represent, and be proportional to, the spaces BC, CD, EF, FG , which are described during the moments bc, cd, ef, fg .

Draw tp parallel to ag , so as to make the rectangle $btpc$ equal to the trapezium $bikc$; and draw the lines qv, ur, sx , in the same manner, so that each rectangle may be equal to its corresponding trapezium.

If the motions had been uniform during the moments bc and fg , that is, if the spaces BC and FG had been uniformly described, then the velocity in the point C would have been to the velocity in the point F as cp to fs : For since the rectangles $btpc$ and $fsxg$ are respectively equal to the trapeziums $bikc$ and $fno g$; and since $bikc$ is to $fno g$ as BC is to FG , the rectangle $btpc$ is to the rectangle $fsxg$ as BC to FG . But because these two rectangles have equal altitudes bc and fg , they are to each other in the proportion of their bases cp and gx , or cp and fs . Therefore BC is to FG as cp to fs . But if BC and FG are uniformly described in equal times, they are proportional to the velocities of those uniform motions. Therefore cp is to fs as the velocity with which BC is uniformly described to the velocity with which FG is uniformly described in an equal time.

But the motion expressed by the figure is not uniform, because the line blo recedes from the axis ag , and the areas, cut off by the parallel ordinates, increase in a greater proportion than the corresponding parts of the axis; that is, the spaces increase faster than the times: for the moments bc, cd, ef, fg , being all equal, it is evident that the corresponding slips of the area continually augment. The motion is swifter at the instant c than at the instant b , and the velocity at the instant c is greater than that with which the space BC would be uniformly described in the same time. For the same reason, the velocity at the instant f is less than that with which the space FG would be uniformly described in the same time. Therefore the velocity at the instant c is to the velocity at the instant f in a greater ratio than that of cp to fs . In the very same manner, it will appear by comparing the motion during the moment

cd

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$c d$ with the motion during the moment ef , that the velocity at the instant c is to the velocity at the instant f in a less ratio than that of $c q$ to fr .

Therefore the velocity in the point C is to the velocity in the point F in a greater ratio than that of $c p$ to fs , but in a less ratio than that of $c q$ to fr .

But by continually diminishing the equal moments bc, cd, ef, fg , it is evident that cp and cq continually approach to equality with ck ; and fr and fs , continually approach to equality with fn , that when cp is less than ck , fs is greater than fn , and when cq is greater than cb , fr is less than fn .

Therefore the velocity in the point C is to the velocity in the point F in a ratio that is greater than the ratio of any line less than ck to any line greater than fn , but which is less than the ratio of any line greater than ck to any line less than fn . Therefore the ratio of the velocity in C to the velocity in F is greater than any ratio that is less than that of ck to fn ; but it is less than any ratio that is greater than that of ck to fn . Therefore the velocity in the point C is to the velocity in the point F as ck to fn .

This important theorem may be expressed in more general terms as follows:

If the abscissa ag of a line hko represent the time of any motion, and if the areas bounded by parallel ordinates be proportional to the spaces described, the ordinates are proportional to the velocities.

REMARK. The propriety or aptitude of expressing the time by the portions of the axis acg , will, perhaps, appear more clearly in the following manner.

Let acg be any straight line, and let hkv be another line, straight or curved. Let the straight line abz , perpendicular to ag , be carried uniformly down along this line, keeping always perpendicular to it, and therefore always parallel to its first position abz . In its various situations $ckz, emz, &c.$ it will cut off areas $ackb, aemb, &c.$ bounded by the axis by the ordinates ah and ck , or by the ordinates ab and $cm, &c.$ and by the line hkg . By this motion the moveable ordinate is said, in the language of modern geometry, to generate the areas $ackb, aemb, &c.$ At the same time, let a point A move along the line ACG , setting out from A at the instant when the line az sets out from a ; and let the motion of the point A be so regulated, that the spaces $AB, AC, AD, &c.$ generated by this motion, may increase at the same rate with the areas, $ab, ib, ackb, adlb, &c.$ or such that we shall have AB to AC as abi , to $ackb, &c.$ It is plain, that the motion along AG is the same with that described in the enunciation of the proposition: for because the motion of the ordinate az , along the axis ag , is supposed to be uniform, the spaces $ab, ac, ad, &c.$ are proportional to the times in which they are described, and may therefore be taken to measure or to represent those times.

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COR. 1. *In a motion continually varied, the velocities in the different points of the path are to each other in the limiting or ultimate ratio of the spaces described in equal times, those times being supposed to diminish continually: for it is evident, that if the equal moments bc, cd, ef, fg , are supposed to diminish continually, till the instants b and d coalesce with c , and the instants e and g coalesce with f ; then the ratio of ck to fn is*

the limit of the continually increasing ratio of cp to fs , or of the continually diminishing ratio of cq to fr . Sir Isaac Newton calls this the ultimate ratio of cp to fs , or of cq to fr . Now the ratio of cp to fs is, by construction, the same with the ratio of the rectangle $btpc$ to the rectangle $fsxg$, and the ratio of cq to fr is the same with the ratio of the rectangle $cqv d$ to the rectangle $eurf$. But the ratio of the rectangle $btpc$ to the rectangle $fsxg$ is the same with the ratio of the space $bikc$ to the space $fnog$; that is (by hypothesis), the same with the ratio of the space BC to the space FG ; and the ratio of the rectangles $cqv d$ and $eurf$ is the same with that of the spaces CD and EF . Therefore the ratio of the velocity at C to the velocity at F is the same with the ultimate ratio of the small increments BC, FG , or CD, EF of the spaces generated in very small and equal times.

It is also evident, that because the ratio of ck to fn is the limit both of the ratio of cp to fs and of the ratio of cq to fr , these ultimate ratios are the same, and that we may say that the velocity in C is to the velocity in F in the ultimate ratio of BC to EF , or in the ultimate ratio of CD to FG .

We also can easily perceive, that the ratio of the area $bikc$ to the area $emnf$ approaches more near to the ratio of ck to fn as we take the moments bc and ef smaller. Therefore, in many cases of practice, where it may be easy to measure the spaces described in the different small moments of the motion, but difficult to ascertain their ultimate ratio, so as to obtain accurate measures of the proportions of the velocities, we may reduce the errors of measurement to something very insignificant, by taking these moments extremely small; and we shall diminish the error still more, by taking the proportion of the half sum of BC and CD to the half sum of EF and FG for the proportion of the velocities in C and F .

It often happens that we have it not in our power to compare the spaces described in small moments which are precisely equal. Still we can find the exact proportion of the velocities, if we can ascertain the ultimate ratio of the increments of the spaces, and the ultimate ratio of the moments of time in which these increments are described: for it is plain, by considering the gradual approach of the points p and r to the points k and n , that the ratio of ck to fn is still the ultimate ratio of the bases of rectangles equal to the mixtilineal areas, whether the altitudes (representing the moments) are equal or not. Now the bases of two rectangles are in the proportion of the rectangles directly, and of their altitudes inversely. But the ultimate ratio of the altitudes is the ultimate ratio of the moments, and the ultimate ratio of the rectangles is the ultimate ratio of the spaces described in those unequal moments. Therefore, in such cases, we have,

COR. 2. *The velocities are in the ratio compounded of the direct ultimate ratio of the momentary increments of the spaces, and the inverse ultimate ratio of the increments (or moments) of the times in which these increments of the spaces are made.*

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If s, v , and t , are taken to represent the magnitudes of the spaces, velocities, and times, and if s, v , and t , are taken always in the limiting or ultimate ratio of their momentary increments, we shall have v always in the

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the proportion of s directly, and of t inversely. We express this by the proportional equation $v \propto \frac{s}{t}$, which

the first of these two propositions, which enables us to ascertain the velocity of the motion in its different moments. Thus if we observe, that a stone in falling descends one foot in the quarter of a second, 16 feet in a second, 64 feet in two seconds, and 144 feet in three seconds; the general law immediately observed is, "that the spaces described are as the squares of the times;" for 1 is to 16 as the square of $\frac{1}{4}$ th to the square of 1. Again, 16 is to 64 as 1^2 to 2^2 ; and 16 is to 144 as 1^2 to 3^2 . Hence we infer, with great probability, that the stone would fall 36 feet in a second and a half; for 16 is to 36 as 1^2 to $1\frac{1}{2}^2$; and we conclude in the same way for all other parts of the motion.

is equivalent to the analogy $V : v = \frac{\dot{S}}{T} : \frac{s}{t}$, or $V : v = \dot{S}t : sT$.

This immediate observation of the analogy between a good example of the geometrical method. The spaces and the squares of the times suggests an easy determination of the velocity in this particular kind of motion; and it merits particular notice, being very often referred to. We can take ag to represent the time; and then, because the areas which are to represent the spaces described must be proportioned to the squares of the portions of ag , we perceive that the line which comes in place of bko must be a straight line drawn from a . For example, the straight line ads . For this is the only boundary which will give areas $abb\beta$, $acc\alpha$, $add\delta$, &c. proportional to a^2 , a^2 , a^2 , &c. And we perceive that any straight line drawn from a will have this property.

75. *N. B.* Here observe, that this is not the only way of stating the relation of space and time—the abscissa may be made the time, and the ordinate the space; then the velocity $= \frac{y}{x}$.

The converse of this proposition may be thus expressed.

76. Converse theorem.

If the axis ag of the line hko represent the time of a varied motion along the line AG , and if the ordinates ah , bi , ck , &c. be as the velocities in the instants a , b , c , or in the points A , B , C ; then the areas $abih$, $ackh$, $allh$, &c. are proportional to the spaces AB , AC , AD , &c.

This may be demonstrated in the same way with the former; but the indirect demonstration is more brief, and equally strict.

If the spaces AC , AF , &c. are not proportional to the areas $ackb$, $afnb$, &c. they are proportional to some other areas $ackb'$, $afnb'$, &c. which are bounded by the same ordinates, and by another line $b'kn'$. But because the areas $ackb'$, $afnb'$, &c. are always proportional to the spaces AC , AF , &c. described on the line AG , the velocity in the point C is to the velocity in the point F as the ordinate ck is to the ordinate fn' . But, by hypothesis, the velocity in C is to the velocity in F as ck to fn , and fn' is equal to fn ; which is absurd. Therefore the spaces AC , AF , are not proportional to any other areas, &c.

77. *Cor.* The ultimate ratio of the momentary increments of the spaces is compounded of the ratio of the velocities, and the ultimate ratio of the increments of the times: for when the moments bc , ef , are equal, it is evident that the ultimate ratio of the rectangles bcp , $efru$ is the same with the ultimate ratio of the increments of the spaces. But the ultimate ratio of these rectangles is the same with their bases cp and fr ; that is, the ratio of ck to fn , that is, the ratio of the velocities. And when the moments are unequal, the ratio of the rectangles is compounded of the ratio of their bases and the ratio of their altitudes; that is, compounded of the ratio of the velocities and the ultimate ratio of the moments of time.

We have, therefore, $\dot{S} : s = \dot{V}T : vt$, and $s \propto vt$. It most commonly happens, that we can only observe the accumulated results of varied motions; and in them we only observe a space passed over, and a certain portion of time that has elapsed during the motion. But being able to distinguish the portions of the whole space which are described in known portions of the whole time, and having made such observations in several parts of the motion, we discover the general law that the motion affects, and we affirm this law to hold universally, even though we have not observed it in every point. We do this with a degree of probability and confidence proportioned to the frequency of our observation. It is not till we have done this that we can make use of

Having thus got our representations of the times and the spaces, we say, on the authority of our theorem, that the velocity at the instant b is to the velocity at the instant d as $b\beta$ to $d\delta$, &c. And now we begin to make inferences, purely geometrical, and express our discovery of the velocities in a very general and simple manner. We remark, that $b\beta$ is to $d\delta$ as ab is to ad ; and we make the same affirmation concerning the magnitudes represented by these lines. We say that the velocity at the instant b is to the velocity at the instant d as the time ab is to the time ad . We say, in terms still more general, that the velocities are proportional to the times from the beginning of the motion. We moreover perceive, that the spaces are also proportional to the squares of the acquired velocities; or the velocities are as the square roots of the spaces.

We can farther infer, from the properties of the triangle, that the momentary increments of the spaces are proportional to the momentary increments of the squares of the times, or of the squares of the velocities.

We also observe, that not only the whole acquired velocities are proportional to the whole elapsed times, but that the increments of the velocities are proportional to the times in which they are acquired; for πz is to ρr as bc to df , &c. Equal increments of velocity are therefore acquired in equal times. Therefore such a motion may, in great propriety of language, be denominated a UNIFORMLY ACCELERATED MOTION; that is, a motion in which we observe the spaces proportioned to the squares of the times, is a motion uniformly accelerated; and spaces in the duplicate ratio of the times form the ostensible characteristic of an uniformly accelerated motion.

Lastly, if we draw $\epsilon\lambda$ parallel to the axis ab , we perceive that the rectangle $ae\epsilon\lambda$ is double of the triangle $ae\epsilon$. Now because ae represents the time of the motion, and $e\epsilon$ represents the acquired velocity, the rectangle $ae\epsilon\lambda$ will represent the space which would be uniformly described with the velocity $e\epsilon$ during the time

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ac. But the triangle *ac* represents the space really described by the uniformly accelerated motion during the same time. Hence we infer, that the space that is described in any time, with a motion increasing uniformly from nothing, is one-half of the space which would be uniformly described during the same time with the final velocity.

These are but a part of the inferences which we may draw from the geometrical properties of those representations which we had selected of the different measurable affections of motion. We may affirm, with respect to the motions themselves, all the inferences which relate to magnitude and proportion, and thus improve our knowledge of the motions.

We took the opportunity of this very simple and perspicuous example, to give our young readers a just conception of the *mathematical method* of prosecuting mechanical knowledge, and to make them sensible of the unquestionable authority for every theorem deduced in this manner.

One of the most important is, to discover the accumulated result of a motion of which we only observe the momentary increments. This is to be done by finding the area, or portions of the area, of the mixtilineal space *agob*; and it is evidently analogous to the inverse method of fluxions, or the integral calculus.

In most cases, we must avail ourselves of the corollary $s = vt$, and we obtain the solution of our question only in the cases where our knowledge of the quantities *s*, *t*, and *v* (considered as geometrical magnitudes, that is, as lines and surfaces), enables us to discover *s* and *t*.

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HAVING thus discovered the proportions of the velocities in motions varying in any manner whatever, we can observe the variations which happen in them. These variations are the effects, and the only marks and measures, of the changing forces. They are the characteristics of their kinds (considered merely as moving forces); that is, the indications of the directions in which they act; for this is the only difference in kind of which they are susceptible in this general point of view. If they increase the velocity, their direction must be conceived as the same with that of the previous motion; because the result of the action of a force is equivalent to the composition of the motion which that force would produce in a quiescent body with the motion already existing: and an increase of velocity is equivalent to the composition of a motion in the same direction.

Having no other mark of the force but the acceleration, we have no other name for it in the abstract doctrines of dynamics, and we call it an **ACCELERATING FORCE**. Had it retarded the motion, we should have called it a **RETARDING FORCE**.

In like manner, we have no measure of the *magnitude* or *intensity* of an accelerating force, but the acceleration which it produces. In order therefore to investigate the powers which produce all the changes of motion, we must endeavour to obtain measures of the acceleration.

A continual increase of velocity is the effect of the continued action of accelerating forces. If equal increments of velocity are produced in every succeeding equal moment of time, we cannot conceive that there is

any change in the accelerating force. Therefore a uniformly accelerated motion is the mark of the unvaried action of an accelerating force, that is, of the continued action of a constant force; of a force whose intensity is always the same. When therefore we observe a body describe spaces proportional to the squares of the times, we must infer that it is urged forward by a force whose intensity does not change; and, on the other hand, a constant force must produce a uniformly accelerated motion by its continued action. And if any previous circumstances assure us of this continued action of an invaried force, we may make all the inferences which were mentioned under the article of uniformly accelerated motion.

That force must surely be accounted double which produces a double increment of velocity in the same time by its uniform action, we can form no other estimation of its magnitude. And, in general, *accelerating forces must be accounted proportional to the increments of velocity which they produce, by acting uniformly during the same or equal times.*

Supposing them to act on a body at rest. Then the velocity produced is itself the increment; and we must say, that accelerating forces are proportional to the velocities which they generate in a body in equal times. And because we found (*n* 79.), that the space described with a uniformly accelerated motion is half the space which would be uniformly described in the same time with the final velocity, which space is the direct measure of this velocity, and because halves have the same proportion with the wholes—we may say that *accelerating forces are proportional to the spaces through which they impel a body from rest in equal times by their uniform action.*

This is an important remark; because it gives us an easy measure of the force, without the trouble of first computing the velocities. It also gives us the only distinct notion that we have of the measurement of forces by the motions which they produce. When speaking of the composition of forces, we distinguished or denominated them by the sides and diagonal of a parallelogram. These lines must be conceived as proportional to the spaces through which the forces urge the body *uniformly* during the small and insensible time of their action, which time is supposed to be the same for both forces; for the sides of the parallelogram are supposed to be separately described in equal times, and therefore to be proportional to the velocities generated by the constituent forces. If indeed the forces do not act uniformly, nor similarly, nor during equal times, we cannot say (without farther investigation) what is the proportion of the intensity of the forces, nor can we infer the composition of their action. We must at least suppose, that in every instant of this very small time of their joint action, their direction remains unchanged, and that their intensities are in the same ratio. We shall see by and bye, that with these conditions the sides of the parallelogram are still proportional to the velocities generated. In the mean time, we may take the spaces through which a body is uniformly impelled from rest (that is, with a uniformly accelerated motion) as the measures of the forces; yet these spaces are but the halves of the measures of the velocities. Then, if a body be moving with the velocity of 32 feet per second, and an accelerating force acts on it during a second,

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Measure of an accelerating force.

Another measure.

and

Of Accelerating and Retarding Forces. and if this force be such that it would impel the body (from a state of rest) 16 feet, it will add to the body a velocity of 32 feet per second. Accordingly, this is the effect of gravity—the weight of a pound of lead may be considered as a force which does not vary in its intensity. We know that it will cause the lead to fall 16 feet in a second; but if the body has already fallen 16 feet, we know that it is then moving with the velocity of 32 feet per second. And the fact is, that it will fall 48 feet farther in the next second, and will have acquired the velocity of 64 feet per second. It has therefore received an augmentation of 32 feet of velocity by the action of gravity during the 2d second; and gravity is in fact a constant force, causing equal increments of velocity in equal times, however great the velocities may be. It does not act like a stream of fluid, whose impulse or action diminishes as the solid body withdraws from it by yielding.

But supposing that we have not compared the increments of velocity uniformly acquired during equal times, in what manner shall we measure the accelerating forces? In such a case, that force must be accounted double which generates the same velocity, by acting uniformly during half the time; for when the force is supposed invariable, the changes of velocity which it produces are proportional to the times of its action; therefore if it produces an equal velocity in half the time, it will produce a double velocity in an equal time, and is therefore a double force. The same may be said of every proportion of time in which an equal change of velocity is produced by the uniform action of an accelerating force. The force must be accounted greater in the same proportion that the time required for the production of a given velocity in a body is less. Hence we infer, that *accelerating forces are inversely proportional to the times in which a given change of velocity is produced by their uniform action.*

By combining these two propositions we establish this general theorem:

82 Measure of accelerating force, *Accelerating forces are proportional to the changes of velocity which they produce in a body by their uniform action directly, and to the times in which these changes are produced inversely.*

If, therefore, A and a are the forces, V' and v' the changes of velocity, and T' and t' the portions of time in which they are uniformly produced, we have

$$A : a = V' t' : v' T', = \frac{V'}{T'} : \frac{v'}{t'}$$

$$\text{And } a \doteq \frac{v'}{t'}$$

The formula $a \doteq \frac{v'}{t'}$ is not restricted to any particular magnitude of v' and t'. It is true, therefore, when the portion of time is diminished without end; for since the action is supposed uniform, the increment of velocity is lessened in the same proportion, and the value of the fraction $\frac{v'}{t'}$ remains the same. The characters or symbols v' and t' are commonly used to express finite portions of v and t. The symbols \dot{v} and \dot{t} are used by Newton to express the same things taken in the ultimate or limiting ratio. They are usually considered as indefinitely small portions of v and t. We shall

abide by the formula $a \doteq \frac{\dot{v}}{\dot{t}}$.

It must always be kept in mind, that v and t are abstract numbers; and that v refers to some unit of space, such as a foot, an inch, a yard; and that t refers to some unit of time, such as an hour, a minute, a second; and especially that a is the number of the same units of space, which will be uniformly described in one unit of the time with the velocity generated, by the force acting uniformly during that unit. It is twice the space actually described by the body during that unit when impelled from rest by the accelerating force. It is necessary to keep hold of these clear ideas of the quantities expressed by the symbols.

On the other hand, when the measure of the accelerating force is previously known, we employ the theorem $a t' = v'$; that is, the addition made to the velocity during the whole, or any part, of the time of the action of the force is obtained by multiplying the acceleration of one unit of time by the number of such units contained in t'.

These are evidently leading theorems in dynamics; because all the mechanical powers of nature come under the predicament of accelerating or retarding forces. It is the collection of these in any subject, and the manner in which they accompany, or are inherent in it, which determine the mechanical character of that subject; and therefore the phenomena by which they are brought into view are the characteristic phenomena. Nay, it may even be questioned, whether the phenomena bring any thing more into view. This force, of which we speak so familiarly, is no object of distinct contemplation; it is merely a something that is proportional

to $\frac{\dot{v}}{\dot{t}}$. And when we observe, that the $\frac{\dot{V}}{\dot{T}}$, found in the motions that result from the vicinity of a body A, is double of the $\frac{\dot{v}}{\dot{t}}$, which results from the vicinity of

another body B; we say that a force resides in A, and that it is double of the force residing in B. The accelerations are the things immediately and truly expressed by these symbols. And the whole science of dynamics may be completely taught without once employing the word *force*, or the conception which we imagine that we form of it. It is of no use till we come to study the mechanical history of bodies. Then, indeed, we must have some way of expressing the fact, that

an acceleration = $\frac{32 \text{ feet}}{1''}$ is observed in every thing on the surface of this globe; and that an acceleration = $\frac{418 \text{ feet}}{1''}$ is observed over all the surface of the sun. These facts are characteristic of this earth and of the sun; and we express them shortly by saying, that such and such forces reside in the earth and in the sun. It will preserve us from many mistakes and puzzling doubts, if we resolutely adhere to this meaning of the term *force*; and this will carry mathematical evidence through the whole of our investigations.

As velocity is not an immediate object of contemplation, and all that we observe of motion is a space and a time, it may be proper to give an expression of this measure of accelerating force which involves no other idea. Supposing the body to have been previously at rest, we have $a \doteq \frac{\dot{v}}{\dot{t}}$. Multiply both parts

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83 Is an abstract number.

Measure of a change of velocity.

These measures express the greatest part of our knowledge of mechanical nature.

84 Another measure of accelerating force.

Of Accelerating and Retarding Forces. of the fraction by t , which does not change its value, and we have $a \doteq \frac{v t}{t^2}$. But $v t = s$; and therefore a

$$\doteq \frac{s}{t^2}.$$

The formula $a = \frac{s}{t^2}$ is equivalent to the proportion $t^2 : 1 = s : a$; and a would then be the space through which the accelerating force would impel the body in one unit of the time t . But this is only half of the measure of the velocity which the accelerating force generates during that unit of time. For this reason we did not express the accelerating force by an ordinary equation, but used the symbol \doteq . In this case, therefore, of uniform action, we may express the accelerating force by $a = \frac{2s}{t^2}$.

The following theorem is of still more extensive use in all dynamical disquisitions.

85 Most general measure of accelerating force. *Accelerating forces are proportional to the momentary increments of the squares of the velocities directly, and as the spaces along which they are uniformly acquired inversely.*

Let $A'B$, $A'C$, and AD (fig. 14.), be three lines, described in the same or equal times by the uniform action of accelerating forces; the motions along these lines will be uniformly accelerated, and the lines themselves will be proportional to the forces, and may be employed as their measures. On the greatest of them AD , describe the semicircle $ABCD$, and apply the other two lines $A'B$, $A'C$ as chords AB , AC . Draw EB , FC perpendicular to AD . Take any small portions Bb , Cc of AB and AC , and draw be , cf perpendicular to AD , and Eh and Fk parallel to AB and AC .

Then, because the triangles DAB and BAE are similar, we have $AD : AE = AD^2 : AB^2$. And because AD is to AB as the velocity generated at D is to the velocity generated at B (the times being equal), we have AD to AE as the square of the velocity at D to the square of the velocity at B ; which we may express thus:

$$AD : AE = V^2, D : V^2, B.$$

For the same reasons we have also

$$AD : AF = V^2, D : V^2, C. \text{ Therefore}$$

$$AE : AF = V^2, B : V^2, C.$$

But because in any uniformly accelerated motion, the spaces are as the squares of the acquired velocities, we have also

$$AE : Ae = V^2, B : V^2 b, \text{ and}$$

$$AF : Af = V^2, C : V^2 c.$$

Therefore Ee is to Ff as the increment of the square of the velocity acquired in the motion along Bb to the increment of the square of the velocity acquired along Cc .

But, by similarity of the triangles ABD and Eeb , we have

$$AB : AD = Ee : Eb; \text{ and, in like manner,}$$

$$AD : AC = Ff : Fc. \text{ Therefore}$$

$$AB : AC = Ee \times Fc : Ff \times Eb.$$

Now AB and AC are proportional to the forces which accelerate the body along the lines $A'B$ and $A'C$; Ee and Ff are proportional to the increments of the squares of the velocities acquired in the motions

along the portions Bb and Cc ; and Eh and Fk are Of Accelerating and Retarding Forces. equal to those portions respectively. The ratio of AB to AC is compounded of the direct ratio of Ee to Ff ; and the inverse ratio of Eh to Fk . The proposition is therefore demonstrated.

The proportion may be expressed thus:

$$AB : AC = \frac{Ee}{Eb} : \frac{Ff}{Fk}, \text{ and may be expressed by}$$

the proportional equation $AB \doteq \frac{Ee}{Eb}$ or, symbolically, $a \doteq \frac{v^2}{s}$.

REMARK. Because the motion along any of these three lines is uniformly accelerated, the relation between spaces, times, and velocities, may be represented by means of the triangle ABC (fig. 15.); where AB represents the time, BC the velocity, and ABC the space. If BC be taken equal to AB , the triangle is half of the square $ABCF$ of the velocity BC ; and the triangle ADE is half of the square $ADEG$ of the velocity DE . Let Dd and Bb be two moments of time, equal or unequal. Then $DdeE$ and $BbcC$ are half the increments of the squares of the velocities DE and BC , acquired during the moments Dd and Bb . It was demonstrated, that the ratio of the area $DdeE$ to the area $BbcC$ is compounded of the ratio of DE to BC , and the ultimate ratio of Dd to Bb . But Dd and Bb are respectively equal to ϵe and $\times c$. Therefore $DdeE$ is to $BbcC$, in the ratio compounded of the ratio of DE to BC , and the ultimate ratio of ϵe to $\times c$. If we represent DE and BC by V and v , then ϵe and $\times c$ must be represented by V' and v' , the increments of V and v ; and then the compounded ratio will be the ratio of VV' to vv' ; and if we take the ultimate ratio of the moments, and consequently the ultimate ratio of the increments of the velocities, we have the ratio of VV' to vv' . If, therefore, V^2 and v^2 represent the squares of the velocities, VV' and vv' will represent not the increments of those squares, but half the increments of them.

We may now represent this proposition concerning accelerating forces by the proportional equation $a \doteq$

$$\frac{v v'}{s}; \text{ and we must consider this as equivalent with } a =$$

$\frac{V^2 - v^2}{2(S - s)}$; keeping always in mind, that a , V , and v , relate to the same units of time and space, and that a is that number of units of the scale on which S and s are measured, which is run over in one unit of time.

This will be more clearly conceived by taking an example. Let us ascertain the accelerative power of gravity, supposing it to act uniformly on a body. Let the spaces be measured in feet and the time in seconds. It is a matter of observation, that when a body has fallen 64 feet, it has acquired a velocity of 64 feet per second: and that when it has fallen 144 feet, it has acquired the velocity of 96 feet per second. We want to determine what velocity gravity communicated to it by acting on it during one second. We have $V^2 = 9216$, and $v^2 = 4096$; and therefore $V^2 - v^2 = 5120$. $S = 144$, and $s = 64$, and $S - s = 80$, and $2(S - s) = 160$. Now $a = \frac{5120}{160} = 32$. Therefore gravi-

Of Accelerating and Retarding Forces. 80. ty has generated the velocity 32 feet per second by acting uniformly during one second.

The augmentation of the square of the velocity is proportional to the force and to the space jointly. For, because

$$a = \frac{v \dot{v}}{s}, \text{ we have } a s = v \dot{v}.$$

Thus we learn, that a given force acting uniformly on a body along a given space, produces the same increment of the square of the velocity, whatever the previous velocity may have been. Also, in the same manner as we formerly found that the augmentation of the velocity was proportioned to the time during which the force has acted, so the augmentation of the square of the velocity is proportional to the space along which it has acted.

It is pretty plain, that all that we have said of the uniform action of an accelerating force may be affirmed of a retarding force, taking a diminution or decrement of velocity in place of an increment. A uniformly retarded motion is that in which the decrements of velocity in equal times are equal, and the whole decrements are proportional to the whole times of action. Such a motion is the indication of a constant or invariable force acting in a direction opposite to that of the motion. We conceive this to be the case when an arrow is shot perpendicularly upwards; its weight is conceived as a force continually pressing it perpendicularly downwards.

In such motions, however great the initial velocity may be, the body will come to rest; because a certain determined velocity will be taken from the body in each equal successive moment, and some multiple of this will exceed the initial velocity. Therefore the velocity will be extinguished before the end of a time that is the same multiple of the time in which the velocity was diminished by the quantity above mentioned. It is no less evident, that the time in which any velocity will be extinguished by an opposing or retarding force, is equal to the time in which the same force would generate this velocity in the body previously at rest. Therefore,

- 87. 1. The times in which different initial velocities will be extinguished by the same opposing force are proportional to the initial velocities.
- 88. 2. The distances to which the body will go till the extinction of its velocity are as the squares of the initial velocities.
- 89. 3. They are also as the squares of the times elapsed.
- 4. The distance to which a body, projected with any velocity, will go till its motion be extinguished by the uniform action of a retarding force, is one half of the space which it would describe uniformly during the same time with the initial velocity.

Forces generally variable in their intensity. Ir very rarely happens, that the force which accelerates the body acts uniformly, or with an unvaried intensity. The attraction of a magnet, for example, increases as the iron approaches it. The pressure of a spring diminishes as it unbends. The impulse of a stream of water or wind diminishes as the impelled surface retires from it by yielding. Therefore the effects of accelerating forces are very imperfectly explained, till we have shewn what motions result from any given variation of force, and how to discover the variation of force from the observed motion. This last question is per-

haps the most important in the study of mechanical nature. It is only thus that we learn what is usually called the nature of a mechanical force. This chiefly consists in the relation subsisting between the intensity of the force and the distance of the substance in which it resides. Thus the nature of that power which produces all the planetary motions, is considered as ascertained when we have demonstrated that its pressure or intensity is inversely as the square of the distance from the body in which it is supposed to reside.

Acceleration expresses some relation of the velocity and time. This relation may be geometrically expressed in a variety of ways. In figure 13. the uniform acceleration or the unvaried relation between the velocity and the time is very aptly expressed by the constant ratio of the ordinates and abscissas of the triangle agv . The ratio of ds to ad is the same with that of es to ae , or that of fs to af , &c.; or the ratio of the increment of velocity ωx to the increment of the time $\beta \omega$ or bc , or that of $i \phi$ to ei , &c. This ratio $\omega x : \beta \omega$ is equivalent to the symbol $\frac{v}{t}$.

But when the spaces described in a varied motion are represented by the areas bounded by a curve line bko , we no longer have that constant ratio of the increments of the ordinates and abscissas.

Therefore in order to obtain measures of the accelerating forces, or at least of their proportions, let the abscissa ae (fig. 13.) of the line bko again represent the time of a motion. But let the areas bounded by parallel ordinates now represent the velocities, that is, let the whole area increase during the time ag at the same rate with the velocities of the motion along the line AG . In this case the ordinates $bi, ck, dl, \&c.$ will be as the accelerations at the instants $b, c, d, \&c.$ or in the points $B, C, D, \&c.$

This is demonstrated in the same way as the former proposition (n^o 72.). If the accelerating force be supposed constant during any two equal moments bc and fg , the rectangles $bcpt$ and $fgxs$ would express the increments of velocity uniformly acquired in equal times, and their bases cp and fs would have the ratio of the accelerations, or of the accelerating forces. But as the velocities expressed by the figure increase faster than the times during every moment, the force at the instant c is to the force at the instant f in a greater ratio than that of cp to fs ; but, for similar reasons, it is in a less ratio than that of cq to fr ; and therefore (as in the other proposition) the force at the instant c is to the force at the instant f as ck to fn .

Cor. Because cp is to fs in the ratio compounded of the direct ratio of the rectangle $cptb$ to the rectangle $fsxg$, and the inverse ratio of the altitude bc to the altitude fg ; and because these rectangles are proportional to the increments of velocity, and the ultimate ratio of the altitudes is the ultimate ratio of the moments or increments of the time—we must say, that the accelerating forces (that is, their intensities or pressures producing acceleration) are directly as the increments of velocity, and inversely as the increments of the times: Which proposition may be expressed, in regard to two accelerations A and a , by this analogy:

$$A : a = \frac{\dot{V}}{T} : \frac{\dot{v}}{t}.$$

3 X 2

Or

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90 Their measures in such cases how obtained? Theorem of most extensive use.

91

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Or by the proportional equation $a \propto \frac{v}{t}$. Also $a \cdot t \propto v$, and $\int a \cdot t = v$. And thus do these theorems extend even to the cases where there cannot be observed an immediate measure, either of velocity or of acceleration; because neither the space nor the velocity increases uniformly.

See Barrow's Lect. Geometr. passim.

The theorem $a \propto \frac{v}{t}$ is employed when we would discover the variation in the intensity of some natural power. We observe the motion and represent it by a figure analogous to fig. 13. where the abscissa represents the times, and the area is made to increase at the same rate with the spaces described. Then the ordinates will represent the velocities, or have the proportion of the velocities. Then we may draw a second curve, on the other side of the same abscissa, such that the areas of this last curve shall be proportioned to the ordinates of the first. The ordinates of this last curve are proportional to the accelerating forces.

92. On the other hand, when we know from other circumstances that a force, varying according to some known law, acts on a body, we can determine its motion. The intensity of the force in every instant being known, we can draw a line so related to another line representing the time that the ordinates shall be proportional to the forces: The areas will be proportional to the velocities. We can draw another curve to the same absciss, such that the ordinates of this shall be proportional to the areas of the other, that is, to the velocities of the motion. The areas of this second curve will be proportional to the spaces described.

93. All these theorems relate to changes of velocity; by which means they indicate immediately the operation of natural powers.

We must now observe, that all that has been said concerning the effects of accelerating forces continually varying, relates to changes of motion, independent of what the absolute motions may be. The areas of the line whose ordinates represent the velocities do not necessarily represent the spaces described, but the change made on the spaces described in the same time, not the motions, but the changes of motion. If, indeed, the body be supposed to be at rest when the forces begin to act, these areas represent the very spaces that are passed over, and the ordinates are the very velocities. In every case, however, the accelerations are the real increments of the velocities.

This circumstance gives a great extension to our theorems, and enables us to ascertain the disturbances of any species of regular motion, apart from the motions themselves, and thus avoid a complication which would frequently be inextricable in any other way. And this process, which is merely mathematical, is perfectly conformable to mechanical principles. It is in fact an application of the doctrine of the composition of motion; a doctrine rigidly demonstrated when we measure a mechanical force by the change of motion which it produces. Acceleration is the continual composition of a new motion with the motion already produced.

No finite change of velocity can be produced in an instant by any accelerations, and they are represented by the ordinates of the line $h k o$, the increment of velocity is represented

We may learn from this investigation of the value of an accelerating force, that no finite change of velocity is effected in an instant by the action of an accelerating force. When the fig. 13. is used for the scale of accelerations, and they are represented by the ordinates of the line $h k o$, the increment of velocity is represented

by an area, that is, by a slip of the whole area; which slip must have some altitude, or must occupy some portion of the abscissa which represents time. Some portion of time, however small it may be, must elapse before any measurable addition can be made to the velocity. The velocity must change continually. As no motion can be conceived as instantaneous, because this would be to conceive, that in one instant the moving particle is in every point of its momentary path; so no velocity can change, by a finite quantity, in one instant; because this would be to conceive, that in that instant the particle had all the intervening velocities. The instant of change is at once the last instant of the preceding velocity, and the first of the succeeding, and therefore must belong to both. This cannot be conceived, or is absurd. As a body, in passing from one part of space to another, must pass in succession through all the intermediate places; so, in passing from one velocity to another, it must in succession have all the intermediate velocities. It must be continually accelerated; we must not say gradually, however small the steps.

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But to return from this digression:

The most frequent cases which come under examination do not shew us the relation between the forces and times, but the relation between the forces and spaces. Thus, when a piece of iron is in the neighbourhood of a magnet, or a planet is considered in the neighbourhood of the sun, a force is acting on it in every point of its path, and we have discovered that the intensity of this force varies in a certain proportion. Thus, a spring varies in its pressure as it unbends; gunpowder presses less violently as it expands, &c. &c.

94. More convenient manner of considering the action of forces, and more frequently coming into view.

Our knowledge is generally confined to some such effect as this. We know, that while a body is moving along a line ADE (fig. 16.), it is urged forward by a force, of which the intensity varies in the proportion of the ordinates BF, CG, DH, EI, &c. of the line FGHI.

To investigate the motion or change of motion produced by the action of this force, let CD be supposed a very small portion of the space s , which we may express by s' . Draw GK perpendicular to DH. Then, if we suppose that the force acts with the unvaried intensity CG through the whole space CD, the rectangle CDKG will express half of the increment of the square of the velocity (n° 85.). We may suppose that the force acts uniformly along the adjoining small space Dr with the intensity DH. The rectangle DH or will in like manner express another half increment of the square of the velocity. And in like manner we may obtain a succession of such increments. The aggregate or sum of them all will be half the difference between the square of the velocity at B and the square of the velocity at E.

If we employ f to express the indetermined or, variable intensity of the accelerating force, and v to express the variable velocity, and v its increment uniformly acquired; then the rectangle CDKG will be expressed by $f s'$. We have seen that this is equal to $v v'$. Therefore, in every case where we can tell the aggregate of all the quantities $f s$, it is plain that we will obtain half the difference between the squares of the velocities in B and E, on the supposition that the intensity of the force was constant along each little space, and varied.

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varied by starts. Then, by increasing the number, and diminishing the magnitude, of those little portions of the space without end, it is evident that we terminate in the expression of the real state of the case, *i. e.* of a force varying continually; and that in this case the aggregate of these rectangles occupies the whole area AEIF, and is equivalent to the fluent of $f's$, or to the symbol $\int f's$, used by the foreign mathematicians to express this fluent, which they indeed conceive as an aggregate of small rectangles $f's$. And we see that this area expresses half of the augmentation of the square of the velocity. Therefore,

If the abscissa AE (fig. 16.) of a line FGI is the path along which a body is urged by any accelerating force, and if the ordinates BF, CG, DH, &c. are proportional to the forces acting on the points B, C, D, &c. the intercepted areas BCGF, BEIF, &c. are proportional to the augmentations of the square of the velocity.

Observe that the areas BCGF and DEIH are also proportional to the augmentations made on the squares of the velocities in B and D.

Observe also, that it is indifferent what may have been the original velocity. The action of the forces represented by the ordinates make always the same addition to its square; and this addition is half the square of the velocity which those forces would generate in the body by impelling it from rest in the point A.

Lastly, on this head, observe, that we can state what constant or variable force will make the same augmentation of the square of the velocity by impelling the body uniformly along the same space BE; or along what space a given force must impel the body, in order to produce the same increase of the square of its velocity. In the first case, we have only to make a rectangle BEN ϕ , equal to the area BEIF, and then B ϕ is the intensity of the constant force wanted. In the second case, in which the force EO is given, we must make the rectangle A ϕ OE equal to the area BEIF, and AE is the space required.

The converse of this proposition, *viz.* If the areas are as the increments of the square of the velocity, the ordinates are, as the forces, is easily demonstrated in the same way; for if the elementary areas CDKG and EIM e represent increments of the squares of the velocity, the accelerating forces are in the ratio compounded of the direct ratio of these rectangles and the inverse ratio of their altitudes, because these altitudes are the increments of the space (n $^{\circ}$ 85.). Now the base CG of the rectangle CDKG, is to the base EI of the rectangle EIM e in the same compounded ratio; therefore the force in C is to the force in E as CG to EI.

The line hko (fig. 13.) was called by Dr Barrow (who first introduced this extensive employment of motion into geometry), the SCALE of velocities; and the line FHL (fig. 16.) was named by him the scale of accelerations. Hermann, in his *Phoronomia*, calls it the scale of forces. We shall retain this name, and we may call hko of fig. 13. the scale of accelerations, when the areas represent the velocities. Sir Isaac Newton added another scale of very great use, *viz.* a scale of times. It is constructed as follows.

Let ABE (fig. 16.) be the line along which a body is accelerated, and let FHI be the scale of forces, that is, having its ordinates FB, HD, IE, &c. proportional

to the forces acting at B, D, E, F, &c.; let fhi be another line so related to ABE, that Cg is to Ei in the inverse subduplicate ratio of the area BFGC to the area BFIE; or, to express it more generally, let the squares of the ordinates to the line fgi be inversely, as the areas of the line FHI intercepted between these ordinates and the first ordinate drawn through B; then the times of the bodies moving from a state of rest in B are as the intercepted areas of the curve fgi .

For let CD and Ee be two very small portions of the space described in equal times. They will be ultimately as the velocities in C and E. The area FBCG is to the area FB EI as the square of Ei to the square of Cg (by construction); but the area FBCG is to FB EI as the square of the velocity at C is to the square of the velocity at E (by the proposition); therefore the square of the velocity at C is to the square of the velocity at E as the square of Ei to the square of Cg; therefore Ei is to Cg as the velocity at C to the velocity at E, that is, as CD to Ee: but since $Ei : Cg = CD : Ee$, we have $Ei \times Ee = Cg \times CD$, and the elementary rectangles CgkD and Eime are equal, and may represent the equal moments of time in which CD and Ee were described. Thus the areas of the line fgl will represent or express the times of describing the corresponding portions of the abscissa.

We may express the nature of this scale more briefly thus. Let BE be the space described with any varied motion, and fgl a curve, such that its ordinates are inversely as the velocities in the different points of the abscissa, then the area will be as the times of describing the corresponding portions of the abscissa.

In all the cases where our mathematical knowledge enables us to assign the values of the ordinates of the figure 16, we can obtain the law of action of the forces; or the nature of the force; and where we can assign the value of the areas from our knowledge of the proportions of the ordinates or forces, we can ascertain the velocities of the motion. We shall give an example or two, which will shew the way in which we avail ourselves of the geometrical properties of figure, in order to ascertain the effects of mechanical forces.

1. Let the accelerating force which impels the body along the line AB be constant, and let the body be previously at rest in B; the line which bounds the ordinates that represent the forces must be some line ϕ HN parallel to AB. The area BDH ϕ is to the area BEN ϕ as the square of the velocity at D to the square of the velocity at E. These areas, having equal bases DH and EN, are as their altitudes BD and BE; that is, the spaces described are as the squares of the acquired velocities. And we see that this characteristic mark of uniformly accelerated motion is included in this general proposition.

2. Let us suppose that the body is impelled from A (fig. 17.) towards the point C, by a force proportional to its distance from that point. This force may be represented by the ordinates DA, EB, eb , &c. to the straight line DC. We may take any magnitude of these ordinates; that is, the line DC may make any angle with AC. It will simplify the investigation if we make the first force AD = AC. About C describe the circle AH a , cutting the ordinate EB in F; let eb be another ordinate, cutting the circle in f very near

100 Examples of the application of n $^{\circ}$ 95.

101 Example second of peculiar importance.

95 Most important theorem (Newton's Principia, l. 39.)

96.

97 Converse.

98 Scales of force, velocity, acceleration, time, &c.

99.

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to F; draw CH perpendicular to AC, and make the arch $Hb = fF$, and draw bc parallel to HC; join FC and DH, and draw Fg perpendicular to fb . Let IML be another ordinate.

The area DABE is to the area DAKL as the square of the velocity at B to the square of the velocity at K. But DABE is the excess of the triangle ADC above the triangle EBC, or it is half of the excess of the square of CA or CF above the square of CB, that is, half the square of BF. In like manner, the area DAKL is equal to half the square of KM; but halves have the same ratio as the integers; therefore the square of BF is to the square of KM as the square of the velocity at B to the square of the velocity at K; therefore the velocity at B is to the velocity at K as BF is to KM. The velocities are proportional to the sines of the arches of the quadrant AFH described on AC.

Cor. 1. The final velocity with which the body arrives at C, is to the velocity in any other point B as radius to the sine of the arch AF.

Cor. 2. The final velocity is to the velocity which the body would acquire by the uniform action of the initial force at A as 1 to $\sqrt{2}$; for the rectangle DA CH expresses the square of the velocity acquired by the uniform action of the force DA; and this is double of the triangle DAC; therefore the squares of these velocities are as 1 and 2, and the velocities are as $\sqrt{1}$ and $\sqrt{2}$, or as 1 to $\sqrt{2}$.

Cor. 3. The time of describing AB is to the time of describing AC as the arch AF to the quadrant AFH.

102.

For when the arch Ff is diminished continually, it is plain that the triangle fiF is ultimately similar to CFB, by reason of the equal angles Cib (or CFB) and fiF , and the right angles CBF and fFi ; therefore the triangles fgF and CBF are also similar. Moreover, Bb is equal to Fg, Ff is equal to bH, which is ultimately equal to cC; therefore since the triangles fgF and CFB are similar, we have $Fg : Ff = FB : FC = FB : HC$; therefore Bb is to cC as FB to HC, that is, as the velocity at B to the velocity at C; therefore Bb and cC are described in equal moments when indefinitely small; therefore equal portions Ff, bH, of the quadrant correspond to equal moments of the accelerated motion, along the radius AC; and the arches AF, FM, MH, &c. are proportional to the times of describing AB, BK, KC, &c.

Cor. 4. The time of describing AC with the unequally accelerated motion, is to the time of describing it uniformly with the final velocity as the quadrantal arch is to the radius of a circle; for if a point move in the quadrantal arch so as to be in F, f, M, H, &c. when the body is in B, b, K, C, it will be moving uniformly, because the arches are proportional to the times of describing those portions of AC; and it will be moving with the velocity with which the body arrives at C, because the arch bH is ultimately = cC. Now if two bodies move uniformly with this velocity, one in the arch AFH, and the other in the radius AC, the times will be proportional to the spaces uniformly described; but the time of describing AFH is equal to the time of the accelerated motion along AC; therefore the proposition is manifest.

103.

Cor. 5. If the body proceed in the line Ca, and be retarded in the same manner that it was accelerated

along AC, the time of describing AC uniformly with the velocity which it acquires in C is to the time of describing ACa with the varied motion, as the diameter of a circle to the circumference; for because the momentary retardations at K', B', &c. are equal to the accelerations at K and B, &c. the time of describing ACa is the same with that of describing AHa uniformly with the greatest velocity. That is, to the time of describing AC uniformly as AHa to AC, or as the circumference of a circle to the diameter. Therefore, &c. N. B. In this case of retarding forces it is convenient to represent them by ordinates K'L, BE, aD', lying on the other side of the axis ACa; and to consider the areas bounded by these ordinates as subtractive from the others. Thus the square of the velocity at K' is expressed by the whole area DACK'L'D, the part C'K'L being negative in respect of the point DAC. This observation is general (See also OPTICS, no 125, *Encycl.*)

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Cor. 6. The time of moving along KC, the half of AC, by the uniform action of the force at A, is to that of describing ACa by the varied action of the force directed to C, and proportional to the distance from it, as the diameter of a circle to the circumference; for when the body is uniformly impelled along KC by the constant force IK, the square of the velocity acquired at C is represented by half the rectangle IKCH, and therefore it is equal to the velocity which the variable force generates by impelling it along AC (by the way, an important observation). The body will describe AC uniformly with this velocity in the same time that it is uniformly accelerated along KC. Therefore by Cor. 5. the proposition is manifest.

Cor. 7. If two bodies describe AC and KC by the action of forces which are every where proportional to the distances from C, their final velocities will be proportional to the distances run over, and the times will be equal.

For the squares of the final velocities are proportional to the triangles ADC, LKC, that is, to AC^2 , KC^2 , and therefore the velocities are as AC, KC. The times of describing AC and KC uniformly, with velocities proportional to AC and KC, must be equal; and these times are in the same ratio (*viz.* that of radius to $\frac{1}{2}$ th of the circumference) to the times of describing AC and KC with the accelerated motion. Therefore, &c.

Thus, by availing ourselves of the properties of the circle, we have discovered all the properties or characters of a motion produced by a force always directed to a fixed point, and proportional to the distance from it.

Some of these are remarkable, such as the last corollary; and they are all important; for there are innumerable cases where this law of action obtains in Nature. It is nearly the law of action of a bow string, and of all elastic bodies, when their change of figure during their mutual action is moderate; and it has been by the help of this proposition, first demonstrated in a particular case by Lord Brouncker and Mr Huyghens, that we have been able to obtain precise measures of time, and consequently of actual motions, and consequently of any of the mechanical powers of Nature. It is for this reason, as well as for the easy and perspicuous employment of the mathematical method of proceeding, that we have selected it.

Instead of giving any more particular cases, we may observe

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observe in general, that if the intensity of the force be proportional to any power whose index is $n - 1$ of the distance, and if a be the distance from the fixed point at which the body begins to be accelerated, and x its distance from that point in any part of the motion, the velocity will be $\dot{x} \doteq \sqrt{a^n - x^n}$. This is very plain, because the increment CGHD of the area of fig. 16. which is also the increment of the square of the velocity, is $\dot{x} \doteq x^{n-1} \dot{x}$, and the area is $\dot{x} \doteq x^n$; and the whole area, corresponding to the distance a , is a^n . Therefore the portion of the area lying beyond the distance x is $a^n - x^n$. This is as the square of the velocity, and therefore the velocity is as the square root $\sqrt{a^n - x^n}$ of this quantity.

This proposition, $f \dot{s} \doteq v \dot{v}$, or $f \doteq \frac{v \dot{v}}{s}$, is the

39th of the first book of Newton's *Principia*, and is perhaps the most important in the whole doctrine of dynamics, whether employed for the investigation of forces or for the explanation of motions. It furnishes the most immediate data for both purposes, but more especially for the last. By its help Sir Isaac Newton was able to point out the numerous disturbances of the planetary motions, and to separate them from each other; thus unravelling, as it were, that most intricate motion in which all are blended together. He has given a most wonderful specimen of its application in his Lunar Theory.

We now are able to explain all the puzzling facts which were adduced by Leibnitz and his partisans in support of their measure of the forces of bodies in motion. We see why four springs, equally bent, communicate but a double velocity, and nine springs but a triple velocity; why a bullet moving twice as fast will penetrate an earthen rampart to a quadruple depth, &c. &c.

Conservatio virium vivarum.

This theorem also gives a most perspicuous explanation of the famous doctrine called *conservatio virium vivarum*. When perfectly elastic bodies act on each other, it is found that the sum of the masses multiplied by the squares of the velocities is always the same. This has been substituted, with great encomiums, by the German philosophers in place of Des Cartes's principle, that the quantity of motion in the universe, estimated in one direction, remains always the same. They are obliged, however, to acknowledge, that in the actions of perfectly hard bodies, there is always a loss of *vis viva*, and therefore have denied the existence of such bodies. But there is the same loss in the mutual actions of all soft or ductile, or even imperfectly elastic, bodies; and they are miserably puzzled how to explain the fact; but both the *conservatio* and the *amissio* are necessary consequences of this theorem.

In the collision of elastic bodies, the whole change of motion is produced during the short time that the bodies are compressed, and while they regain their figure. When this is completed, the bodies are at the same distance from each other as when the mutual action began. Therefore the preceding body has been accelerated, and the following body has been retarded, along equal spaces; and in every point of this space the accelerating and the retarding force has been equal. Consequently the same area of fig. 17. expresses the change

made on the square of the velocity of both bodies. Therefore, if V and U are the velocities before collision, and v and u the velocities after collision, of the two bodies A and B , we must have $A \times V^2 - v^2 = B \times U^2 - u^2$, and therefore $A \times V^2 + B \times U^2 = A \times v^2 + B \times u^2$.

But in the other class of bodies, which do not completely regain their figure, but remain compressed, they are nearer to each other when their mutual action is ended than when it began. The foremost body has been accelerated along a shorter space than that along which the other has been retarded. The mutual forces have, in every instant, been equal and opposite. Therefore the area which expresses the diminution of the square of the velocity, must exceed the area expressing the augmentation by a quantity that is always the same when the permanent compression is the same; that is, when the relative motion is the same. $A \times V^2 - v^2$ must exceed $B \times U^2 - u^2$, and $A \times V^2 + B \times U^2$ must exceed $A \times v^2 + B \times u^2$.

This same theorem is of the most extensive use in all practical questions in mechanic arts; and without it mechanics can go no farther than the mere statement of equilibrium.

Hermann, professor of mathematics at Pavia, one of the ornaments of the mathematical class of philosophers, has given a pretty demonstration of this valuable proposition in the *Acta Eruditorum Lipsiæ* for 1709; and says, that having searched the writings of the mathematicians with great care, he found himself warranted to say, that Newton was the undoubted author, and boasts of his own as the first synthetical demonstration. The purpose of this assertion was not very apparent at the time; but long after, in 1746, when Hermann's papers, preserved in the town-house of Pavia, were examined, in order to determine a dispute between Maupertuis and Koenig about the claim to the discovery of the principle of least action, letters of Leibnitz's were found, requesting Hermann to search for any traces of this proposition in the writings of the mathematicians of Europe. Leibnitz was by this time the envious detractor from Newton's reputation; and could not but perceive, that all his contorted arguments for his doctrine received a clear explanation by means of this proposition, in perfect conformity to the usual measure of moving forces. Newton had discovered this theorem long before the publication of the *Principia*, and even before the discovery of the chief proposition of that book in 1666; for in his Optical Lectures, the materials of which were in his possession in 1664, he makes frequent use of a proposition founded on this (see no 42.) We may here remark, that Hermann's demonstration is, in every step, the same with Dr Barrow's demonstration of it as a theorem merely geometrical, without speaking of moving forces (see *Lect. Geometr.* xi. p. 85. edit. 16.) but giving it as an instance of the transformation of curves, which he calls SCALES of velocity, of time, of acceleration, &c. It is very true that Barrow, in these mathematical lectures, approached very near to both of Newton's discoveries, the fluxionary geometry, and the principles of dynamics; and the junto on the continent, who were his continual detractors, charge him with impudent plagiarism from Dr Barrow, and even say that he has added nothing to the discoveries of his teacher. But surely Dr Barrow was the best judge of this mat-

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History of no 95. is curious.

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ter; and so far from resenting the use which Newton has made of what he had taught him, he was charmed with the genius of the *juvenis spectatissimus* his scholar, and of his own accord gave him his professorial chair, and ever after lived in the utmost harmony and friendship with him. Nay, it would even appear, from some expressions in those very lectures, that Dr Barrow owed to young Newton the first thought of making such extensive use of motion in geometry. We recommend this work of Barrow's to the serious perusal of our readers, who wish to acquire clear notions of the science of motion, and an elegant taste in their mechanical disquisitions. After all the cultivation of this science by the commentators and followers of Newton, after the *Phoronomia* of Hermann, the *Mechanica* of Euler, the *Dynamique* of D'Alembert, and the *Mechanique Analytique* of De la Grange, which are undoubtedly works of transcendent merit and utility, the *Principia* of Newton will still remain the most pleasing, perspicuous, and elegant specimen of the application of mathematics to the science of *universal mechanics*, or what we call *DYNAMICS*.

The two fundamental theorems $f \dot{t} = \dot{v}$, and $f \dot{v} = v \dot{v}$, enable us to solve every question of motion accelerated or retarded by the action of the mechanical powers of nature. But the employment of them may be greatly expedited and simplified by noticing two or three general cases which occur very frequently.

104 Similar instants and points, what?

These may be called *similar instants of time*, and *similar points of space* which divide given portions of time, and of space in the same ratio. Thus the middle is a similar instant of an hour or of a day, and is the similarly situated point of a foot or of a yard. The beginning of the 21st minute, and of the 9th hour, are similar instants of an hour and of a day. The beginning of the 5th inch, and of the 2d foot, are similar points of a foot and of a yard.

105 Similar actions, what?

Forces may be said to act *similarly* when their intensities in similar instants of time, or in similar points of space, are in a constant ratio. - Thus in fig. 17. when one body is impelled towards C from A, and another from K, each with a force proportional to the distance of every point of its motion from C, these forces may be said to act similarly along the spaces AC and KC, or during the times represented by the quadrantal arches AFH, KNO. The following propositions on similar actions will be found very useful on many occasions; but we must premise a geometrical lemma.

106.

If there be two lines EFGH (fig. 18.), $efgb$, so related to their abscissæ AD, ad , that the ordinates IK, ik , drawn from similar points I and i of the abscissæ, are in the constant ratio of AE to ae ; then the area ADHE is to the area $adbe$ as the rectangle of AD \times AE to the rectangle $ad \times ae$.

For let each abscissa be divided into the same number of equal and very small parts, of which let CD and cd be one in each. Inscribe the rectangles CGID, $cgid$. Then because the number of parts in each axis is the same, the lengths of the portions CD and cd will be proportional to the whole abscissæ AD and ad . And because C and c are similar points, CG is to cg as AE is to ae . Therefore $CD \times CG : cd \times cg = AD \times AE : ad \times ae$. This is true of each pair of corresponding rectangles; and therefore it is true of their sums. But when the number of these rectangles is in-

creased, and their breadth diminished without end, it is evident that the ultimate ratio of the sum of all the rectangles CDHG to the sum of all the rectangles $cdhg$, is the same with that of the area ADHE to the area $adbe$, and the proposition is manifest.

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If two particles of matter are similarly impelled during given times, the changes of velocity are as the times and as the forces jointly.

107.

Let the times be represented by the straight lines ABC (fig. 19.) and abc , and the forces by the ordinates AD, BE, CF, and ad, be, cf . Then if B and b are similar instants (suppose the middles) of the whole times, we have $BE : be = AD : ad$. Therefore, by the lemma, the area ACDF is to $acfd$ as $AC \times AD$ to $ac \times ad$. But these areas are proportional to the velocities (n^o 72), and the proposition is demonstrated. For the same reason the change of velocity during the time AB is to the change during ab as $AB \times AD$ to $ab \times ad$.

Cor. 1. If the times and forces are reciprocally proportional, the changes of velocity are equal; and if the forces are inversely as the times, the changes of velocity are equal.

If two particles be similarly urged along given spaces, the changes made on the squares of the velocities are as the forces and spaces jointly.

108.

For if AC (fig. 19.) and ac are the spaces along which the particles are impelled, and the forces are as the ordinates AD and ad , the areas ACFD and $acfd$ are as the changes on the squares of the velocities. But these areas are as $AC \times AD$, and $ac \times ad$. Therefore, &c.

Cor. 2. If the spaces are inversely as the forces, the changes of the squares of the velocities are equal; and if these are equal, the spaces are inversely as the forces.

Cor. 3. If the spaces, along which the particles have been impelled from a previous state of rest, are directly as the forces, the velocities are also as the forces. For, because the changes of the squares of the velocities are as the spaces and forces jointly, they are in this case as the squares of the forces or of the spaces; but the changes of the squares of the velocities are in this case the whole squares of the velocities; therefore the squares of the velocities are as the squares of the forces, and the velocities are as the forces. N. B. This includes the motions represented in fig. 17.

If two particles be similarly impelled along given spaces, from a state of rest, the squares of the times are proportional to the spaces directly, and to the forces inversely.

109.

Let ABC (fig. 19.) abc be the spaces described, and AD, ad , the accelerating forces at A and a . Let V, B express the velocity at B, and v, b the velocity at b .

Let GHK and ghk be curves whose ordinates are inversely as the velocities at the corresponding points of the abscissa. These curves are therefore exponents of the times (n^o 99). Then, because the forces act similarly, we have, by the last theorem, $AC \times AD : ac \times ad = V^2 : v^2, b = hb^2 : HB^2$. Therefore $HB : hb = \sqrt{ac \times ad} : \sqrt{AC \times AD}$, and therefore in a constant ratio. Call this the ratio of m to n . But, since the ordinates of the lines GHK, ghk are inversely as the velocities, the areas are as the times (n^o 99); and

Of Accelerating and Retarding Forces. and since these ordinates are in the constant ratio of m to n , the areas are in the ratio of $AC \times m$ to $ac \times n$. Therefore (calling the times of the motions T and t), we have

$$\begin{aligned} T : t &= m AC : nac; \text{ and therefore} \\ T^2 : t^2 &= m^2 \times AC^2 : n^2 \times ac^2. \text{ But} \\ m^2 : n^2 &= ac \times ad : AC \times AD. \text{ Therefore} \\ T^2 : t^2 &= ac \times ad \times AC^2 : AC \times AD \times ac^2, \\ \text{Or } T^2 : t^2 &= ad \times AC : AD \times ac. \\ \text{Or } T^2 : t^2 &= \frac{AC}{AD} : \frac{ac}{ad}. \end{aligned}$$

The attentive reader will observe that these three propositions give a great extension to the theorems which were formerly deduced from the nature of uniformly accelerated motion, or of uniform action of the forces, and were afterwards demonstrated to obtain in the momentary action of forces any how variable.

The first of the three propositions, $V : v = F \times T : f \times t$, is the extension of the theorem $f \times t = v$. The second, $V^2 : v^2 = F \times S : f \times s$, is the extension of the theorem $f \times s = v \dot{v}$. And the third, $T^2 : t^2 = \frac{S}{F} : \frac{s}{f}$,

is the extension of $f = \frac{\dot{v}}{t}$, or of $f \times (t^2) = \dot{v}$. These theorems hold true of all similar actions; and only for this reason, are true of uniformly accelerated motions, or uniform actions.

There remains one thing more to be said concerning the action of accelerating forces. Their magnitude is ascertained by their effect. Therefore that is to be considered as a double force which produces a double quantity of motion. Therefore when a body A contains twice the number of equal atoms of matter, and acquires the same velocity from the action of the force F that another body a , containing half the number of atoms, acquires from the action of a force f , we conceive F to be double of f . That this is a legitimate inference appears clearly from this, that we conceive the sensible weight of a body, or that pressure which it exerts on its supports, as the aggregate of the equal pressure, of every atom, accumulated perhaps on one point; as when the body hangs by a thread, and, by its intervention, pulls at some machine. Without inquiring in what manner, or by what intervention, this accumulation of pressure is brought about, we see clearly that it results from the equal accelerating force of gravity acting immediately on each atom. When this weight is thus employed to move another body by the intervention of the thread, which is attached to one point perhaps of that body, it puts the whole into motion, generating a certain velocity v in every atom, by acting uniformly during the time t . We conceive each atom to have sustained the action of an equal accelerating force; whose measure is $\frac{v}{t}$. Without considering how this

force is exerted on each atom, or by what it is immediately exerted, or how it is diffused through the body from the point to which the weight of the other body is applied by means of the thread; we still consider it as the aggregate of the action of gravity on each atom of that other body. Moreover, attending only to the motion produced by it, and perhaps not knowing the weight of the impelling body, we measure it, as a moving force, by considering it as the aggregate of the

forces propagated to each atom of the impelled body, and measured by $\frac{v}{t}$. If we know that the impelled body contains the number m of atoms, the aggregate of forces is $m \frac{v}{t}$, or $\frac{mv}{t}$.

But since we measure forces by the quantity of motion which they produce, we must conceive, that when the same force is applied to a body which consists of n particles, and produces the velocity u , by acting uniformly during the same time t , the force $n \frac{u}{t}$ is equal to

$$\text{the force } m \frac{v}{t}.$$

Sir Isaac Newton found it absolutely necessary, in the disquisitions of natural philosophy, to keep this circumstance of acceleration clear of all notions of quantity of matter, or other considerations, and to contemplate the affections of motion only. He therefore considered $\frac{v}{t}$ as the true original measure of accelerating force, and $m \frac{v}{t}$ as an aggregate. He therefore calls the aggregate a *vis motrix*, a *moving force*, measured by the quantity of motion that it generates. And he confines the term *accelerating force* to the quantity $\frac{v}{t}$, measured by the acceleration or velocity only. It would be convenient, therefore, also to confine the symbol f to $m \frac{v}{t}$ and to retain the symbol a for expressing the accelerating force $\frac{v}{t}$.

This appellation of *motive force* is perfectly just and simple; for we may conceive it as the same with the accelerating force which produces the velocity m times v in one particle, by acting on it uniformly during the time t . This motion of one particle having the velocity $m v$, is the same with that of m particles having each the velocity v .

If therefore a motive force f acts on a body consisting of m particles, the accelerating force a is $= \frac{f v}{m t}$.

Therefore the three last propositions concerning the similar, the uniform, or the momentary actions of moving forces, when expressed in the most general terms, are,

$$\begin{aligned} v &= \frac{f}{m t} \\ v u &= \frac{f s}{m}, \text{ or } v u = \frac{f s}{m} \\ a &= \frac{m s}{f} \end{aligned}$$

OF DEFLECTING FORCES.

WHEN we observe the direction of a body to change, we unavoidably infer the agency of a force which acts in a direction that does not coincide with that of the body's motion; and we may distinguish this circumstance by calling it a *DEFLECTING FORCE*. We have already shewn how to estimate and measure this deflecting force, by considering it as competent to the

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III
Moving force, motive force, as distinguished from accelerating force.

III
Deflecting forces.

Aggregate of many equal accelerating forces.

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production of that motion which, when compounded with the former motion, will produce the new motion (n° 44.) Now, as all changes of motion are really compositions of motions or forces, it is evident that we shall explain the action of deflecting forces when we shew this composition.

Alteration of deflections are continual, and produce curvilinear motions.

We may almost venture to say *a priori*, that all deflections must be continual, or exhibit curvilinear motions: for as no finite velocity, or change of velocity, can be produced in an instant by the action of an accelerating force, no polygonal or angular deflection can be produced; because this is the composition of a finite velocity produced in an instant. Deflective motions are all produced by the composition of the former motion, having a finite velocity, with a transverse motion continually accelerated from a state of rest. Of this we can form a very distinct notion, by taking the simplest case of such accelerated motion, namely, an uniformly accelerated motion.

Example Determination of the path.

Let a body be moving in the direction AC (fig. 20.) with any constant velocity, and when it comes to A, let it be exposed to the action of an accelerating force, acting uniformly in any other direction AE. This alone would cause the body to describe AE with a uniformly accelerated motion, so that the spaces AD, AE would be as the squares of the times in which they are described. Therefore, if AB be the space which it would have described uniformly in the time that it describes AD by the action of the accelerating force, and AC the space which it would have described uniformly while it describes AE by the action of the accelerating force—nothing more is wanted for ascertaining the real motion of the body but to compound the uniform motion in the direction AC with the uniformly accelerated motion in the direction AE. AD is to AE as the square of the time of describing AD to the square of the time of describing AE; that is, as the square of the time of describing AB to the square of the time of describing AC; that is, as AB^2 to AC^2 (by reason of the uniform motion in AC). This composition is performed by taking the simultaneous points B, D, and the simultaneous points C, E, and completing the parallelograms ABFD, ACEG. The body will be found in the points F and G in the instants in which it would have been found at B and C by the uniform motion, or in D and E by the accelerated motion. In the same manner may be found as many points of the real path as we please. It is plain that these points will be in a line AFG, so related to AE that $AD : AE = DF^2 : EG^2$; or so related to the original motion AC, that $AB^2 : AC^2 = BF : CG$, &c. This line is therefore a parabola, of which AE is a diameter, DF and EG are ordinates, and which touches AC in A.

And of the motion in this path.

Having thus ascertained the path of the body, we can also ascertain the motion in that path; that is, the velocity in any point of it. We know that the velocity in the point G is to the velocity of the uniform motion in the direction AC as the tangent TG is to the ordinate EG; because this is the ultimate ratio of the momentary increment of the arch AFG to the momentary increment of the ordinate EG. Thus is the velocity in every point of the curve determined. We have taken it for granted, that the line of projection touches the path, and that the direction in every point

is that of the tangent. To suppose that the curve, in any portion of it, coincides with the tangent, is to suppose that the body is not deflected; that is, is not acted on by a transverse accelerating force: And to suppose that the tangent makes a finite angle with any part of the path, is to suppose that the deflection is not continual, but by starts—both of which are contrary to the conditions of the case. No straight line can be drawn between the direction of the body and the succeeding portion of the path, otherwise we must again suppose that the deflection is subfultory, and the motion angular.

113.

But while the investigation is so easy when the direction and intensity of the deflecting force in every point of the curve are known, the investigation of the deflecting force from the observed motion is by no means easy. The observed curvilinear motion always arises from a composition of a uniform motion in the tangent with some transverse motion. But the same curvilinear motion may be produced by compounding the uniform motion in the tangent with an infinity of transverse motions; and the law of action will be different in these transverse motions according as their directions differ. We must learn, not only the intensity of the deflecting force, and the law of its variation, but also its direction in every point of the curve. It is not easy to find general rules for discovering the direction of the transverse force; most commonly this is indicated by extrinsic circumstances. The deflecting force is frequently observed to retide in, or to accompany, some other body. It may be presumed, therefore, that it acts in the direction of the line drawn to or from that body; yet even this is uncertain. The most general rule for this investigation is to observe the place of the body at several intervals of time before and after its passing through the point of the curve, where we are interested to find its precise direction. We then draw lines, joining those places with the places of the tangent where the body would have been by the uniform motion only. We shall perhaps observe these lines of junction keep in parallel positions: we may be assured that the direction of the transverse force is the same with that of any of these lines. This is the case in the example just now given of a parabolic motion. But when these lines change position, they will change it gradually; and their position in the point of contact is that to which their positions on both sides of it gradually approximate.

But all this is destitute of the precision requisite in philosophical discussion. We are indebted to Sir Isaac Newton for a theorem which ascertains the direction of the transverse force with all exactness, in the cases in which we most of all wish to attain mathematical accuracy, and which not only opened the access to those discoveries which have immortalised his name, but also pointed out to him the path he was to follow, and even marked his first steps. It therefore merits a very particular treatment.

If a body describes a curve line ABC, DEF (fig. 21.) lying in one plane; and if there be a point S so situated in this plane that the line joining it with the body describes areas ASB, ASC, ASD, &c. proportional to the times in which the body describes the arches AB, AC, AD, &c. the force which deflects the body from rectilinear motion is continually directed to the fixed point S.

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Newton's fundamental theorem for the direction of the deflecting force.

Of Deflect-
ing Force. Let us first suppose that the body describes the polygon ABCDEF, &c. formed of the chords AB, BC, CD, DE, EF, &c. of this curve: and (for greater simplicity of argument) let us consider areas described in equal successive times; that is, let us suppose that the triangles ASB, BSC, CSD, &c. are equal, and described in equal times. Make $Bc = AB$, and draw cS .

Areas $\frac{1}{2}$ to $\frac{1}{2}$ to the times indicate central forces. Had the motion AB suffered no change in the point B, the body would have described Bc in the equal moment succeeding the first: but it describes BC. The body has therefore been deflected by an external force; and BC is the diagonal of a parallelogram ($u^\circ 45, 46.$), of which Bc is one side, and cC is another. The deflecting force will be discovered, both in respect of direction and intensity, by completing the parallelogram BcCb. Bb is the space which the deflecting force would have caused the body to describe in the time that it describes Bc or BC. Because Bc is equal to BA, the triangles BSc, BSA are equal. But (by the nature of the motion) BSA is equal to BSC. Therefore the triangles BSC and BSc are equal. They are also on the same base BS; therefore they lie between the same parallels, and Cc is parallel to SB. But cC is parallel to Bb. Therefore Bb coincides with BS, and the deflecting force at B is directed toward S. By the same argument, the deflecting force at the angles D, E, F, &c. is directed to S.

Now, let the sides of the polygon be diminished, and their number increased without end. The demonstration remains the same; and continues, when the polygon finally coalesces with the curve, and the deflection is continual.

When areas are described proportional to the times, equal areas are described in equal times; and therefore the deflection is always directed to S. Q. E. D.

Centre of deflection. Centre of forces. Central forces. The point S may, with great propriety of language, be called the CENTRE OF DEFLECTION, or THE CENTRE OF FORCES; and forces which are thus continually directed to one fixed point, may be distinguished from other deflecting forces by the name CENTRAL FORCES.

The line joining the centre of forces with the body, and which may be conceived as a stiff line, carrying the body round, is usually named the RADIUS VECTOR.

Radius vector. 115 Central forces produce areas proportional to the times. The converse of this proposition, viz. that if the deflecting forces be always directed to S, the motion is performed in one plane, in which S is situated, and areas are described proportional to the times—is easily demonstrated by reversing the steps of this demonstration. The motion will be in the plane of the lines SB and Bc; because the diagonal BC of the parallelogram of forces is in the plane of the sides. Areas are described proportional to the times; for Cc being parallel to SB, the triangles SCB and ScB are equal; and therefore SCB and SAB are equal, &c. &c.

116 Velocity is inversely as the perpendicular from the centre. Cor. 1. When a body describes areas round S proportional to the times, or when it is continually deflected toward S, or acted on by a transverse force directed to S, the velocities in the different points A and E of the curve are inversely proportional to the perpendiculars Sr and St, drawn from the centre of forces to the tangents in those points; that is, to the perpendiculars from the centre on the momentary directions of the motion: For since the triangles ASB, ESF are equal,

their bases AB, EF are inversely as their altitudes Sr, St. But these bases, being described in equal times, are as the velocities; and they ultimately coincide with the tangents at A and E.

Cor. 2. If B α and F ϵ be drawn perpendicular to SA and SE, we have $SA \times B\alpha = SE \times F\epsilon$, and $SA : SE = F\epsilon : B\alpha$: For $SA \times B\alpha$ is double of the triangle BSA, and $SE \times F\epsilon$ is double of the equal triangle SFE. 117.

Cor. 3. The angular velocity round S, that is, the magnitude of the angle described in equal times by the radius vector, is inversely proportional to the square of the distance from S. For when the arches AB, EF are diminished continually, the perpendiculars B α and F ϵ will ultimately coincide with arches described round S with the radii SB and SF. Now the magnitude of an angle is proportional to the length of the arch which measures it directly, and to the radius of the arch inversely. In any circle, an arch of two inches long measures twice as many degrees as an arch one inch long; and an arch an inch long contains twice as many degrees of a circle whose radius is twice as short. Therefore, ultimately, the angle ASB is to the angle ESF as B α to F ϵ , and as SF to SB jointly: that is, as $B\alpha \times SF$ to $F\epsilon \times SB$. But $B\alpha : F\epsilon = SE : SA$ (Cor. 2.) Therefore $ASB : ESF = SE \times SF : SB \times SA$, = ultimately $SE^2 : SB^2$. 118

This corollary gives us an ostensible mark, in many very important cases, of the action of a deflecting force being always directed to a fixed point. We are often able to measure the angular motion when we cannot measure the real velocities.

Having thus discovered the chief circumstances which enable us to ascertain the direction of the deflecting force, we proceed to investigate the quantity of this deflective determination in the different points of a curvilinear motion. This is a more difficult task. The momentary effect of the deflecting force is a small deviation from the tangent; and this deviation is made with an accelerated motion. The law of this acceleration regulates the curvature of the path, and is to be determined by it. We may be allowed to observe by the way, that it appears clearly from the form in which Newton has presented all his dynamical theorems, that we are indebted to these problems for the immense improvement which he has made in geometry by his invention of fluxions. The purposes he had in view suggested to his penetrating mind the means for attaining them; and the connection between dynamics and geometry is so intimate, that the same theorems are in a manner common to both. This is particularly the case in all that relates to curvature. Or shall we say that the geometry of Dr Barrow suggested the dynamical theorems to Newton? We have seen how the curvature of a parabola is produced by a force acting uniformly. The momentary action of all finite forces may be considered as uniform; and therefore the curvature will be that of some portion of some parabola; but it will be difficult to determine the precise degree without some farther help. We are best acquainted with the properties of the circle, and will have the clearest notions of the curvature of other curves by comparing them with circles.

The curvature of a circular arch of given length is so much greater as its radius is shorter; for it will contain so many more degrees in the same length; and therefore

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therefore the change of direction of its extremities is so much greater. Curvatures may always be measured by the length of the arch directly and the radius inversely.

119 Evolution and involution of curves.

Suppose a thread made fast at one end of a material curve ABCD (fig. 22), and applied to it in its whole length. Taking hold of its extremity D, unfold it gradually from the curve DCBA; the extremity D will describe another curve Dcba. This geometrical operation is called the EVOLUTION of curves, and Dcba is called the EVOLUTE of DCBA, which is called the INVOLUTE of Dcba. Perhaps this denomination has been given from the genesis of the area or surface contained by the two lines, which is folded up and unfolded somewhat like a fan. When the describing point is in b, the thread bB is, undoubtedly, the momentary radius of a circle ebf, whose centre is B, the point of the involute which it is just going to quit. The momentary motion of b is the same, whether it is describing an arch of the evolute passing through b, or an arch of a circle round the centre B. The same line bt, perpendicular to the thread bB, touches the circle ebf and the curve Dba in the point b. This circle ebf must lie within the curve Dba on the side of bB toward a; because on this side the momentary radius is continually increasing. For similar reasons, the circle ebf lies without the curve on the other side of bB. Therefore the circle ebf both touches and cuts the curve Dba in the point b. Moreover, because every portion of the curve between b and D is described with radii that are shorter than bB, it must be more incurvated than any portion of the circle ebf. For similar reasons, every portion of the curve between b and a must be less incurvated than this circle; therefore the circle has that precise degree of curvature that belongs to the curve in the point b; it is therefore called the EQUICURVE CIRCLE, or the CIRCLE OF CURVATURE, and B is called the centre, and Bb the RADIUS OF CURVATURE. It is easy to perceive that no circle can be described which shall touch the curve in b, and come between it and the circle ebf; for its centre must be in some point i of the radius bB. If ib be less than Bb, it must fall within the curve on both sides of b, and if ib be greater than Bb, the circle must fall without the curve on both sides of Bb. The circle ebf lies closer to the curve, has closer contact with it than any other, and has therefore got the whimsical name of OSCULATING CIRCLE; and this sort of contact was called OSCULATION.

Circle of curvature. Equicurve circle.

This view of the genesis of curve lines is of particular use in dynamical discussions. It exhibits to the eye the perfect sameness of the momentary motion, and therefore of the momentary deflection, in the curve and in the equicurve circle, and leaves the mind without a doubt but that the forces which produce the one will produce the other. A great variety of curves may be described in this way. If perpendiculars be drawn to the curve Dba in every point, they will intersect each other, each its immediate neighbour, in the circumference of the curve DBA: and geometry teaches us how to find the curve DBA which shall produce the curve Dba by evolution. See EVOLUTION and INVOLUTION, Supplement.

It is a matter worthy of remark, that the path of a body that is deflected from rectilinear motion by a fi-

nite force, varying according to any law whatever, may always be described by evolution. This includes almost every case of the action of deflecting forces; none being excepted but when, by the opposite action of different forces, the body is in equilibrium in one single point of its path.

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Our task is now brought within a very narrow compass, namely, to measure the deflection in the arch of a circle.

Had the motion represented in fig. 21. been polygonal, it is plain that the deflecting force in the point B is to that in the point E as the diagonal Bb of the parallelogram ABCb to the diagonal Ei of the parallelogram DEFi; therefore let ABCZY be a circle passing through the points A, B, and C, and let the radius vector BS cut the circumference in Z; draw AZ, CZ, and the diagonal AC, which necessarily bisects and is bisected by the diagonal Bb. The triangles bBC and CBZ are similar; for the angle CbB is equal to the alternate angle ABb or ABZ, which is equal to the ACZ, standing on the same chord AZ. And the angle CBb, or CBZ, is equal to CAZ, standing on the same chord CZ; therefore the remaining angle bCB is equal to the remaining angle AZC; therefore ZA is to AC as BC to Bb, and Bb = $\frac{AC \times BC}{AZ}$. In like manner Ei = $\frac{DF \times EF}{Dz}$.

Now let the points A and C continually approach, and ultimately coalesce with B; it is evident that the circle ABCZY is ultimately the equicurve or coinciding circle at the point B, and that AS ultimately coalesces with, and is equal to, BS, and that AC x BC is ultimately 2BC²; therefore ultimately Bb : Ei = $\frac{2BC^2}{BZ} : \frac{2EF^2}{Ez}$, or = $\frac{BC^2}{\frac{1}{2}BZ} : \frac{EF^2}{\frac{1}{2}Ez}$.

Now BC and EF being described in equal times, are as the velocities: Bb and Ei are the measures of the velocities which the deflective forces at B and E would generate in the time that the body describes BC or EF, and are therefore the measures of those forces. They are as the squares of the velocities directly, and inversely as those chords of the equicurve circles which have the directions of the deflection.

Observe, that Bb or Ei is the third proportional to half of the chord and the arch described; for Bb : BC = BC : $\frac{BZ}{2}$.

It is evident that as the arches AB, BC, continually diminish, AC is ultimately parallel to the tangent Br, and BO is equal to the actual deflection from the tangent. The triangles BOC and AOZ are similar, and BO = $\frac{OC^2}{OZ}$, or ultimately = $\frac{BC^2}{BZ}$. We may measure the forces by the actual deflections, because they are the halves of the measures of the generated velocities; and we may say that

The actual momentary deflection from the tangent is a third proportional to the deflective chord of the equicurve circle and the arch described during the moment.

Either of these measures may be taken, but we must take care not to confound them. The first is the most proper, because the change produced on the body (which is the immediate effect and measure of the force) is the determination, left inherent in it, to move with

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a certain velocity. This is the measure also which we obtain by means of the differential or fluxionary calculus; but the other measure must be obtained when our immediate object is to mark the actual path of the body. What is now delivered coincides with what was more briefly stated in ASTRONOMY, *Suppl.* n^o 16. and is repeated in this place, because the steps of this demonstration, which is Newton's, so naturally terminate in the equicurve circle, and give at once the immediate measure of the deflecting force: at the same time the reader must perceive that this measure does not depend on the force being always directed to one centre; it is enough that the two sides of the polygon, in immediate succession, are described in equal times. This is necessary in order that ABC *b* may be a parallelogram, and that the diagonals AC and B *b* may mutually bisect each other.

Thus have we obtained a measure of deflecting force, and, in the most important cases, a method of discovering its direction. It only remains to point out the relation between the intensity of the force, the curvature of the path, and the velocity of the motion. These three circumstances have a necessary connection; for we see that the intensity is expressed by certain values

of the other two in the formula $f \doteq \frac{\text{Arch}^2}{\frac{1}{2}\text{Chord}^2}$ or $f = \frac{2\text{BC}}{\text{BZ}}$. The deflective velocity B *b* is acquired in

the time that the body describes BC; therefore the deflective velocity is to the velocity in the curve as B *b* to BC. The velocity B *b* is acquired by an accelerated motion along BO; for while, by progressive motion, the body describes BC, it deflects from the tangent through a space equal to the half of B *b*, because the momentary action of the deflecting force may be considered as uniform. The progressive velocity BC may be generated by the same force, uniformly acting through a space greater than BC; call this space *x*. The spaces along which a body must be uniformly impelled in order to acquire different velocities, are as the squares of those velocities; therefore B *b*² : BC² = B *o* : *x*; but B *b* : BC = BC : $\frac{1}{2}$ BZ; therefore B *b*² : BC² = B *o* : $\frac{1}{2}$ BZ, and B *b* : $\frac{1}{2}$ BZ = B *o* : *x*, and B *b* : B *o* = $\frac{1}{2}$ BZ : *x*; but B *o* is $\frac{1}{2}$ of B *b*; therefore *x* is $\frac{1}{2}$ of BZ; that is,

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The velocity in any point of a curvilinear path, is that which the deflecting forces in that point would generate in the body by impelling it uniformly along one fourth part of the deflective chord of the equicurve circle. If the velocity increase, the chord of the equicurve circle must increase; that is, the path becomes less incurvated. If the force be increased, the curvature will also increase, for the chord of curvature will be less.

There is another general observation to be made on the velocity of a curvilinear motion, which greatly assists us in our investigations.

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Comparison of orbital motion with direct approach to the centre.

If a body describes a curve by the action of a force always directed to a fixed point, and varying according to any proportion whatever of the distances from that point, and if another body, acted on by the same centripetal force, move toward the centre in a straight line, and if in any one case of equal distances from the centre of force the two bodies have equal velocities, they will have equal velocities in every other case of equal distances from the centre.

Let one body be impelled from A (fig. 23.) toward C along the straight line AVDEC, and let another be deflected along the curve line VIK *k*. About the centre C describe concentric arches ID, KE, very near to each other, and cutting the curve in I and K, and the line AC in D and E: draw IC, cutting KE in N, and draw NT' perpendicular to the arch IK of the curve, and complete the parallelogram ITNO. Let the bodies be supposed to have equal velocities at I and at D.

Then, because the centripetal forces are supposed to be the same for both bodies when they are at equal distances, the accelerating forces at D and I may be represented by the equal lines DE and IN; but the force IN is not wholly employed in accelerating the body along the arch IK, but, acting transversely, it is partly employed in incurvating the path. It is equivalent to the two forces IO and IT, of which only IT accelerates the body. Now IKN is a right-angled triangle, as is also the triangle INT'; and they are similar; therefore IN : IT' = IK : IN, or DE : IT' = IK : DE; that is, the force which accelerates the body along DE is to the force which accelerates the body along IK as the space IK is to the space DE; therefore (n^o 86.) the increment of the square of the velocity acquired along DE is equal to the increment of the square of the velocity acquired along IK. But the velocities at D and I were equal, and consequently their squares were equal; and these having received equal increments, therefore the squares of the velocities at E and K are equal, and the velocities themselves are equal. And since this is the case in all the corresponding points of the line AC and the curve VIK, the velocities at all equal distances from C will be equal.

It is evident that the conclusion will be the same, if the bodies, instead of being accelerated by approaching the centre in the straight line AC, and in the curve VIK, are moving in the opposite directions from E to A, or from I to V, and are therefore retarded by the centripetal force.

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Cor. Hence it follows, that if a body be projected from any point, such as V, of the curve, in a line tending straight from the centre, with the velocity which it had in that point of the curve, it would go to a distance VA, such, that if it were impelled along AV by the centripetal force, it would acquire its former velocity in the point V; also in any point between V and A it will have the same velocity in its recess from the centre that it has there in its approach to the centre.

Retarded curvilinear motion always accompanied by recess from the centre.

The line BLFG, whose ordinates are as the intensities of the centripetal force in A, V, D, E, or in A, V, I, K, may be called the SCALE or EXPONENT of force; the areas bounded by the ordinates AB, VL, DF, EG, &c. drawn from any two points of the axis, are as the squares of the velocity acquired by acceleration along the intercepted part of the axis, or in any curvilinear path, while the body approaches the centre, or which are lost while the body retires from it. When we can compute these areas we obtain the velocities (see n^o 102.).

We are now in a condition to solve the chief problem in the science of dynamics, to which the whole of it is, in a great measure, subservient. The problem is this,

Let a body be projected with a known velocity from

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a given point and in a given direction, and let it be under the influence of a mechanical force, whose direction, intensity, and variation, are all known: it is required to determine its path, and its motion in this path, for any given time?

This problem is susceptible of three distinct classes of conditions, which require different investigation.

1. The force may act in one constant direction; that is, in parallel lines.
2. The force may be always directed to a fixed point.
3. It may be directed to a point which is continually changing its place.

1. When the force acts in parallel lines, the problem is solved by compounding the rectilinear accelerated motion which the force would produce in its own direction with the uniform motion which the projection alone would have produced. The motion must be curvilinear, when the accelerating force is transverse, in any degree whatever, to the projectile motion; and the curvilinear path must be concave on that side to which the deflecting force tends; for the force is supposed to act incessantly. The place of the body will be had for any time, by finding where the body would have been at the end of that time by each force acting alone, and by completing the parallelogram. Thus, suppose a body projected along AB (fig. 20.) while it is continually acted on by a force whose direction is AD. Let D and B be the places where the body would be at the end of a given time. Then the body will at the end of that time be in F, the opposite angle of the parallelogram ABFD. But it has not described the diagonal AF; because its motion has been curvilinear, as we shall find by determining its place at other instants of this time.

The velocity in any point F is found by first determining the velocity at D, and making DT to DF as the velocity at D to the velocity at B (that is, the velocity of projection, because the motion along AB is uniform). Then draw TF. Then AB is to TF as the constant velocity of projection to the velocity at F. We have seen already (no 112—119.) that TF is a tangent to the curve in F. Hence we may determine the velocity at F in another way. Having determined the form of the path in the way already described, by finding its different points, draw the tangent Fd, cutting the line DA in d. Then the velocity at A is to that at F as AB to dF. Hence also we see, that the velocities in every point of the curve are proportional to the portion of the tangents at those points which are intercepted between any two lines parallel to AD.

Either of these methods for ascertaining the velocity, in this case of parallel deflections, will in general be easier than the general method in no 121. by the equi-curve circle.

It was thus that Galileo discovered the parabolic motion of heavy bodies.

Inverse problem of centripetal forces.

2 We must consider the motions of bodies affected by centripetal or centrifugal forces, always tending to one fixed point. This is the celebrated *inverse problem of centripetal forces*, and is the 42d proposition of the first book of Newton's *Principia*. We shall give the solution after the manner of its illustrious author; because it is elementary, in the purest sense of the word,

keeping in view the two leading circumstances, and these only, namely, the motion of approach and recession from the centre, and the motion of revolution. By this judicious process, it becomes a pattern by which more refined, and, in some respects, better solutions should be modelled. At the same time we shall supply some steps of the investigation which his elegant conciseness has made him omit.

Let a body, which tends to C (fig. 24) with a force proportional to the ordinates of the exponent BLFG, having the axis CA, be projected from V in the direction VQ, with the velocity which the centripetal force would generate in it by accelerating it along AV. It is required to determine the path or orbit VIKI of the body, and its place I in this orbit, at the end of the assigned time T?

Suppose the thing done, and that I is the place of the body. About the centre C, with the distances CV and CI, describe the circles YV and ID. Draw CIX to the circumference, and draw the ordinate DF of the exponent of forces, producing it toward x, and produce the ordinate VL toward a. Let Vt be the distance to which the body would go along the tangent VQ in the time T, and join tC. Let this be supposed done for every point of the curve. Let aik and axy be two curves so related to the curve VIK, that the ordinate DF cuts off an area V a i D equal to the orbital sector VCI, and an area V a x D equal to the circular sector VCX.

Then, because the velocity of projection is given, the distance Vt is known, and the area of the triangle VCt. But this is equal to the area VCI, by the laws of central forces (no 115.). Therefore the area V a i D is given. Also, because the area VCI increases in the proportion of the time, the area V a i D increases at the same rate. Therefore having these subsidiary curves aik, axy, the problem is solved as follows:

Draw the ordinate Di, cutting off an area V a i D proportional to the time, and describe a circle DIR. Then draw a line CX, cutting off a sector VCX, equal to the area V a x D cut off by the ordinate Di x. This line will cut the circle DR in the point I, which is the point of the orbit that was demanded.

But the chief difficulty of the problem consists in the description of the two subsidiary curves aik and axy, into which the lines VIK and VXY are transformed. We attain this construction by resolving the motion in the arch of the orbit into two motions, one of which is in the direction of the transverse force, or of the radius vector, and the other is in the direction of revolution, or perpendicular to the radius.

Let V k and IK be two very small arches described in equal moments, and therefore ultimately in the ratio of the velocities in V and I (no 73.). Describe the circle KE, cutting IC in N. Draw KC and kC, and k n perpendicular to VC.

The element ICK of the orbit is $= \frac{IC \times KN}{2}$, or to $\frac{1}{2} IC \times KN$. This is equal to the element D i k E of the area V a i D, or to D i x DE, or to D i x IN. Therefore IN : KN = $\frac{1}{2} IC : D i$, or 2 IN : KN = IC : D i, and D i = $\frac{IC \times KN}{2 IN}$.

Now let A l f g h be the exponent of the velocities, that

Of Deflect- ing Forces. that is (no 86.), let $V l^2$ be to $D f^2$ as $ABL V$ to $ABFD$, or $V l : D f = \sqrt{ABL V} : \sqrt{ABFD}$. Make $V v$ and $I i$ in the tangents respectively equal to $V l$ and $D f$. Draw $v u$ and $i o$ perpendicular to VC and IC , and $v m$ perpendicular to LV produced. Let $m r$ be an equilateral hyperbola, having VC, ZC , for its asymptotes, and cutting FD produced in r . Then the ordinates $V m, D r$, are inversely proportional to CV, CD , or $V m : D r = CD : CV = CI : CV$. But because the momentary sectors $VC k$ and ICK are equal, $k n : KN = CI : CV$. Therefore,

$$\begin{aligned} V m : D r &= k n : KN \\ \text{but } V v : V m &= V k : k n \\ \text{and } I i \text{ (or } D f) : V v &= IK : V k \\ \text{therefore } I i : D r &= IK : KN \\ \text{but } I i : i o &= IK : KN, \text{ by sim. triang.} \end{aligned}$$

Therefore $D r = i o$, and $i o : V m = VC : CI$. Also, by similarity of triangles, $I o : i o = IN : KN$, and $2 I o : i o = 2 IN : KN$.

Now it was shewn, that in order that the space $D i k E$ may be equal to the space ICK , we must have

$$\begin{aligned} 2 IN : KN &= IC : D i \\ \text{or } 2 I o : i o &= IC : D i \\ \text{but } i o : V m &= VC : IC \\ \text{therefore } 2 I o : V m &= VC : D i \end{aligned}$$

$$\text{and } D i = \frac{VC \times V m}{2 I o}$$

Having obtained $D i$, we easily get $D x$; for the ultimate ratio of ICK to $XC Y$ is that of IC^2 to VC^2 . Therefore make

$$IC^2 : VC^2 = D i : D x.$$

Thus are the points of the two subsidiary curves $a i k, a x y$, determined.

The rectangle $VC \times V m$ is a constant magnitude; and is given, because VC is given, and $V m$ is the given velocity $V l$, diminished in the ratio of radius to the sine of the given angle CVQ .

But the line $2 I o$ is of variable magnitude, but it is also given, by means of known quantities. $I o^2$ is $= I r^2 - i o^2 = D f^2 - D r^2$, and $I o = \sqrt{D f^2 - D r^2}$.

$$\text{Moreover, } D f^2 = ABFD, \text{ and } D r^2 = \frac{VC^2 \times V m^2}{IC^2}.$$

Therefore $2 I o = 2 \sqrt{ABFD - \frac{VC^2 \times V m^2}{IC^2}}$, expressed in known quantities, because $ABFD$ is known from the nature of the centripetal force.

Let the indeterminate distance CI or CD be $= x$, and let the ordinate DF , expressing the force, be y . Let VC be a , and $V m$ be c , and let $a b$ be a rectangle equal to the whole area of the exponent of force lying between the ordinate AB and the ordinate CZ , so that

$a b - \int y x$ may represent the indeterminate area $ABFD$.

$$\text{We have } D i = \frac{a c}{2 \sqrt{a b - \int y x - \frac{a^2 c^2}{x^2}}}$$

$$\text{and } D x = \frac{a^3 c}{2 x^2 \sqrt{a b - \int y x - \frac{a^2 c^2}{x^2}}}$$

REMARK. We have hitherto supposed that the velocity of projection is acquired by acceleration along AV . But this was merely for greater simplicity of ar-

gument, and that the final values of $D i$ and $D x$ might be easier conceived. In whatever way the velocity is acquired, it will still be true, that when in any point V we make $V l$ to $V m$ as the momentary increment $V k$ of the arch is to the perpendicular $k n$ on the radius vector, we shall have in every other point, such as I , the line $D f$ to the line $D r$ as the increment IK of the arch to KN . And in the final equation $D f$ will still be expressed by $\sqrt{a b - \int y x}$.

Cor. 1. The angle which the path of the projectile makes with the radius vector is determined by this solution; for $I i$ is to $i o$ as radius to the sine of this angle; which sine is therefore $= \frac{a c}{x \sqrt{a b - \int y x}}$.

Cor. 2. When the magnitude $\frac{a c}{x}$ is equal to $\sqrt{a b - \int y x}$, the path is perpendicular to the radius vector, and the body is a tone of the apsides of its orbit, and begins to recede from the centre after having approached to it, or begins to approach after having receded.

Cor. 3. The curvature of the orbit $V I K$ is also determined in every point; for the curvature of any line is inversely as the radius of the equicurve circle, and this is to the chord which passes through C as radius to the sine of the angle $CI i$. Because the velocity in any point I is $= \sqrt{ABFD}$, and is equal to what the centripetal force at I would produce, by impelling the body along $\frac{1}{4}$ th of the defective chord of the equicurve circle,

$$\text{we have this chord} = 4 \frac{ABFD}{DF}.$$

Or we obtain it by taking a third proportional to the momentary deflection and the momentary arch of the curve, or by other processes of the higher geometry, all proceeding on the quantities furnished in this investigation.

Such is the solution of this celebrated problem given by Sir Isaac Newton, who may justly be called the inventor of the science of which it is the chief result, as well as of the geometry, by help of which it is prosecuted. For we cannot give this glory to Galileo; for his simple problem of the motion of bodies affected by uniform and parallel gravity, however just and elegant his solution may be, was peculiar; and the same must be said of Mr Huyghens's doctrine of centrifugal forces. Besides, these theorems had been investigated by Newton several years before, *sua mathefi facem preferente*, as corollaries which he could not pass unnoticed, from his general method. This is proved by letters from Huyghens. Newton's investigation is extremely, but elegantly, concise, and is one of the best exertions of his sagacious mind.

Whether we consider this problem as a piece of mere mathematical speculation, or attend to its consequences, which include the whole of the celestial motions in all their extent and complication, we must allow it to be highly interesting, and likely to engage much attention in the period of ardent inquiry which closed the last century. Accordingly, it was no sooner known, by the publication of the *Mathematical Principles of Natural Philosophy* in 1686, than it occupied the talents of the most eminent mathematicians; and many solutions were published, some of which differ considerably from Newton's; some are more expeditious, and better fitted for computation. Of these, the most remarkable

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Apsides determined;

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And curvature.

Newton the inventor.

History of.

for

Of Deflect- ing Forces. for originality and ingenuity are those of de Moivre, Hermann, Keill, and Stewart. The last differs most from the methods pursued by others. M'Laurin's propositions on this subject, and in that part of his fluxions which treats of curvature, are highly valuable, classing the chief affections of curvilinear motions geometrically, as they are suggested by the fluxionary method; and then shewing, in a very instructive manner, the connection between these mathematical affections of motion and the powers of nature which produce them. This part of his excellent work is a fine example of the real nature of all inquiries in dynamics; shewing that it differs from geometry little more than in the language, in which the word *force* is substituted for *acceleration, retardation, or deflection*. We recommend the careful perusal of these propositions to all who wish to have clear conceptions of the subject. Dr John Keill and Dr Horsley (bishop of Rochester) have given particular treatises on the motions of bodies deflected by centripetal forces inversely proportional to the cubes of the distances; induced by the singular motions which result from this law of action, and the multitude of beautiful propositions which they suggest to the mathematician. Newton, indeed, first perceived both of these peculiarities, and has begun this branch of the general problem. He first demonstrated the description of the logarithmic and hyperbolic spirals, and indicated a variety of curious recurring elliptical spirals, which would be described by means of this force, and shewing that they are all susceptible of accurate quadrature. Several of those authors affect to consider their solutions as more perfect than Newton's, and as more immediately indicating the remarkable properties of such motions; and also affect to have deduced them from different and original principles. But we cannot help saying, that their claims to superiority are very ill founded; there is not a principle made use of in their solutions which was not pointed out by Newton, and employed by him. The appearance of originality arises from their having taken a more particular concern in some general property of curvilinear motions; such as the curvature, the centrifugal force, &c. and the making that the leading step of their process. But Newton's is still the best; because it is strictly elementary, aiming at the two leading circumstances, the motion to or from the centre, and the motion of revolution round that centre. To these two purposes he adapted his two subsidiary curves. This procedure became Newton, *pater, et rerum inventor*, who was teaching the world, and who might say,

*Avia Pieridium peragro loca, nullius ante
Trita pede —*

Singular
boast of
John Ber-
noulli.

Is it not surprising, that 25 years after the publication of Newton's *Principia*, a mathematician on the continent should publish a solution in the Memoirs of the French academy, and boast that he had given the first demonstration of it? Yet John Bernoulli did this in 1710. Is it not more remarkable that this should be precisely the solution given by Newton, beginning from the same theorem, the 40th I. Prin. following Newton in every step, and using the same subsidiary lines? Yet so it is. Bernoulli actually reduces the whole

to two functions; namely, $\frac{a^2 c}{\sqrt{a b x^4 - \int \varphi x^4 - \frac{a^2 c^2}{x^2}}}$

and $\frac{a^2 c}{\sqrt{a b x^4 - \int \varphi x^4 - a^2 c^2 x^2}}$; which last is plainly the same with Newton's $\frac{Q \times C X^2}{A^2 \sqrt{A B D F - Z^2}}$; because Newton's $\frac{Q}{A}$ is the same with $\frac{a c}{x}$, and Newton's $A^2 \sqrt{A B D F - Z^2}$ is the same with $x^2 \sqrt{a b - \int \varphi x^4 - \frac{a^2 c^2}{x^2}}$, which Bernoulli has changed (apparently to hide the borrowing) into $\sqrt{a b x^4 - \int \varphi x^4 - a^2 c^2 x^2}$.

Of Deflect- ing Forces.

This publication of Bernoulli is perhaps the most impudent piece of literary robbery, for theft is too mild a term, that has ever appeared; and is the more deserving of severe reprehension, because it is full of reflections on the simple and supremely elegant method of Newton. It is hardly conceivable that a person of Bernoulli's consummate mathematical knowledge was so much blinded by the mechanical procedure of the symbolical calculus (which indeed is rarely accompanied by any ideas of the subject in hand) as not to perceive the perfect sameness of his solution. No; he shews, from time to time, that the physical ideas of motion and force were present to his mind; for he affects to shew, that all Newton's brightest discoveries, such as the proportionality of the areas and times, &c. flow as corollaries from his procedure.

Bernoulli's chief boast in this dissertation is, that *novi* philosophers may be assured that the planets will always describe conic sections; a truth of which they had not as yet received any proof: because, says he, Newton's argument for it in the corollary of the 13th proposition is inconclusive, and because he had not been able to accommodate his demonstration of the 41st and 42d proposition to the particular case of the planetary gravitation. Two assertions that border on insolence. Newton's demonstration in the corollary of the 13th proposition is just, founded on the principle on which the very demonstration of the 42d; adopted by Bernoulli, proceeds, and without which that demonstration is of no force; namely, that a body in given circumstances of situation, velocity, direction, and centripetal force, can describe no other figure than what it really describes. Newton did not accommodate the demonstration of the 42d proposition to the planetary motions, because he had already demonstrated the nature of their orbits; but mentions the case of a force proportional to the reciprocal of the cubes of the distance; not as a deduction from the 42d, but because it *was not* a deduction from it, and admitted a very singular and beautiful investigation by methods totally and essentially different.

Bernoulli also says, that Newton's solution does not give us the notion of a continuous path, as his own does, but only informs us how to ascertain points of this path. This is the boldest of all his assertions. Bernoulli uses the differential calculus. It is the *essential* character of this calculus that it exhibits, and *can* exhibit, nothing but detached points. This is undeniable. And this has been objected to Newton's first proposition. But Newton's fluxionary *geometry*, of which the calculus exhibits only elements (being the same with the differential), supposes

^{Conclusion.} supposes the continuity of all magnitudes; and when applied to dynamics, is no substitution whatever, but the *ipsa corpora*. This geometry offered itself to the mind of Newton, the accomplished and darling scholar of Barrow, whose geometry flashed on Newton's mind as the torch which was to shew him the steps of this yet untrodden path.

We trust that our readers will not be displeas'd with our repeated endeavours to defend our great philosopher from the injurious attacks that have been made on him. During his own illustrious life, while he was diffusing light and knowledge around him, and never contended for fame, happy in being the instructor of mankind, he was injured by those who envied his reputation, while they deriv'd their chief honours from being his best commentators. Now, since he has left this world, he has been more grossly injured by those who avail themselves of that very reputation: and who, by crude and contemptible inferences from his doctrine of elastic undulations, and gross misrepresentations of his notions of an ethereal fluid, have pretended to support a system of materialism; and thus have set Newton at the head of the atheistical sect, which he held in abhorrence. For our part, we always think with pleasure on the wonderful energy of that great mind; because it gives us a foretaste of those pleasures that await the wise and good, when the sorrows flowing from the infirmities, the vices, and the arrogant vanity of man, are past;

*Utique in hoc infelici campo,
Ubi luctus regnat, et pavor,
Mortalibus prorsus non absit solatium.
Hujus enim scripta evolvas,
Mentemque tantarum rerum capacem
Corpori caduco superstitem credas.*

¹³² ^{Conclusion.} It cannot be expected that, in the narrow limits prescribed to a work like ours, we can proceed to consider the various departments of this celebrated problem. We are only giving the outlines of the general doctrines of dynamics; and we have bestowed more time on those which are purely elementary than some readers may think they deserve. We were anxious to give just conceptions of the fundamental principles of dynamics; because we know that nothing else can intitle it to the name of a demonstrative science, and because we see much indistinctness and uncertainty, and a general vagueness or want of precision, in several elementary works which are put into the hands of persons entering on the study. This leads to errors of more consequence than a person is apt to think; because they affect our leading thoughts of mechanism itself, and our notions of the intimate nature of the visible universe.

¹³³ ^{Reasons for} ^{omissions.} But we must conclude the article with this great problem. Many very general doctrines of dynamics remain untouched; all, namely, that relate to the rotative motion of rigid bodies, and all that relate to the mutual action of bodies on each other in the way of impulse.

The rotative motions, with the doctrine of mechanic momenta, have been considered at large in the article *ROTATION* of the *Encycl. Britan.*; and we propose to offer some important considerations on the same subject in our supplement to the articles *MACHINE* and *MECHANICS*. In the article *IMPULSION* will be considered such doctrines as are truly general, and independent of the specific differences of the bodies. **DYNAMICS PRO-**

SUPPL. VOL. I. Part II.

cesses to involve no notions but those of force, and its ^{Conclusion.} marks and measures.

Notwithstanding these great omissions, we must observe that no new principle remains to be considered. We have given all that are necessary; and there is no question that occurs in the cases omitted, which cannot be completely answered by means of the propositions already established. We have taught how to discover the existence and agency of a mechanical force, to measure and characterise it, and then to state what will be its various effects, according to the circumstances of the case.

Proceeding by these principles, men have discovered an universal fact, that every ACTION of one body on another is accompanied by an equal REACTION of that other on the first, in the opposite direction; that is, to express it in the language of dynamics, "all the phenomena which make us infer that the body A possesses a force by which it changes the motion of the body B, shew, at the same time, that B possesses a force by which it makes an equal and opposite alteration in the motion of A." This, however, is not a doctrine of abstract dynamics: it does not flow from our idea of force; therefore it was not included in our list of the LAWS of MOTION. It is a part of the mechanical history of nature, just as the law of universal gravitation is; and it might be called the law of UNIVERSAL REACTION. Sir Isaac Newton has, in our humble apprehension, deviated from his accustomed logical accuracy, when he admits, as a third axiom or law of motion, that reaction is always equal and contrary to action. It is a physical law, in as far as it is observed to obtain through the whole extent of the solar system. But Newton himself did not, in the subsequent part of his noble work, treat it as a logical axiom; that is, as a law of human thought with respect to motion: for he labours with much solicitude, and with equal sagacity, to prove, by *fact and observation*, that it really obtains through the whole extent of the solar system; and it is in this discovery that his chief claim to unequalled penetration and discernment appears.

Availing ourselves of this fact, we, with very little ¹³⁵ ^{Impulsion} trouble, state all the laws of impulsion. The body A, explained for example, moving to the westward at the rate of by it; eight feet per minute, overtakes the double body B, moving at the rate of four feet per minute. What must be the consequence of their mutual impenetrability, and of the equality and contrariety of action and reaction? Their motions must be such that both sustain equal and opposite changes. They must give, in some way or other, *this* indication of possessing equal and opposite forces. This will be the case if, when the changes are completed, A and B move on in contact at the rate of four feet per minute: for here A has produced in each half of B a change of motion two; and therefore a totality of change equal to four. This is the effect, the mark, the measure, of the *impulsive* force of A; for it is the whole *impulsion*. B has produced in A a change of motion four, equal to the former, and in the opposite direction. This is the effect, mark, and measure, of the *repulsive* force of A; for it is the whole *repulsion*. And this is all that we observe in the collision of two lumps of clay; and the observation is one of the facts on which the reality of the physical law of equal action and reaction is founded: and we can make no farther inference from *this* fact.

Conclusion.

But the event might have been very different. A and B may be two magnets floating on corks on water, with their north poles fronting each other. We know, by other means, that they really possess forces by which they equally repel each other. The dynamical principles already established tell us also what must happen in this case. That both conditions of equal reaction and sensible repulsion may be fulfilled, A must come to rest, and B must move forward at the rate of four feet per minute. The same thing must happen in the meeting of perfectly elastic bodies, such as billiard balls. If elasticities are known to be imperfect in any degree, our dynamical principles will still state the effect of their collision, in conformity to the law of equal reaction.

136
And rotation.

In like manner, all the motions of rotation are explained or predicted by means of the same principles of dynamics applied to the force of cohesion. This is considered as a moving force, because, when the attraction of a magnet acts on a bit of iron attached to one end of a long lath floating on water, the whole lath is moved, although the magnet does not act on it at all; some other force acts on it; it is its cohesion; which is therefore a moving force, and the subject of dynamical discussion.

137.

And thus it appears that these subjects do not come necessarily, nor, perhaps, with scientific propriety, under the category of dynamics, but are parts of the mechanical history of nature. Yet, did a work like ours give room in this place, the study of mechanical nature might be considerably improved by giving a system of such general doctrines as involve no other notions but those of force and its measures, and the hypothesis of equal reaction. Some very general, nay universal, consequences of this combination might be established, which would greatly assist the mechanician in the solution of difficult and complicated problems. Such is the proposition, that *the mutual actions of bodies depend on their relative motions only, and require no knowledge of their real motions.* This principle simplifies in a wonderful manner the most difficult and the most frequent cases of action which nature presents to our view; but at the same time gives a severe blow to human vanity, by forcing us to acknowledge that we know nothing of the real motion of any thing in the universe, and never shall know any thing of it till our intellectual constitution, or our opportunities of observation, are completely changed.

138.

Mr D'Alembert has made this principle still more serviceable for extricating ourselves from the immense complication of actions that occurs in all the spontaneous phenomena of nature, by presenting it to us in a different form, which more distinctly expresses what may be called the *elements* of the actions of bodies on each other. His proposition is as follows (*see his Dynamique*, page 73.):

D'Alembert's general principle of dynamics.

"In whatever manner a number of bodies change their motions, if we suppose that the motion which each body would have in the following moment, if it were perfectly free, is decomposed into two others, one of which is the motion which it really takes in consequence of their mutual actions, the other will be such, that if each body were impressed by this force alone (that is, by the force which would produce this motion) the whole system of bodies would be in equilibrium."

This is almost self-evident; for if these second constituent forces be not such as would put the system in equilibrium, the other constituent motions could not be

those which the bodies really take by the mutual action, and would be changed by the first.

Conclusion.

For example, let there be three bodies P, Q, R, and let the forces A, B, C, act on them, such as would give them the velocities p, q, r , in any directions whatever, producing the momenta, or quantities of motion, $P \times p, Q \times q, R \times r$, which we may call A, B, C, because they are the proper measures of the moving force. Let us moreover suppose, that, by striking each other, or by being any how connected with each other, they cannot take these motions A, B, and C, but really take the motions a, b, c . It is plain that we may conceive the motion A impressed on the body P, to be composed of the motion a , which it really takes, and of another motion α . In like manner, B may be resolved into b , which it takes, and another β ; and C into c and γ . The motions will be the same, whether we act on P with the force A, or with the two forces a and α ; whether we act on Q with the force B, or with b and β ; and on R with the force C, or with c and γ . Now by the supposition, the bodies actually take the motions a, b, c ; therefore the motions α, β, γ , must be such as will not derange the motions a, b, c ; that is to say, that if the bodies had only the motions α, β, γ , impressed on them, they would destroy each other, and the system would remain at rest.

Mr D'Alembert has applied this proposition with great address and success to the very difficult questions that occur in the motions and actions of fluids, and many other most difficult problems, such as the precession of the equinoxes, &c. The cause of its utility is, that in most cases it is not difficult to find what forces will put a system in equilibrium; and, combining these with the known extraneous forces whose effects we are interested to discover, we obtain the motions which really follow the mutual action of the bodies.

This is not, properly speaking, a principle: it is a form in which a general fact may be conceived. In the same way the celebrated mathematician De la Grange observed, that a system of bodies acting on each other in any way, is in equilibrium, if there be impressed on its parts forces in the inverse proportion of the velocities which each body takes in consequence of their action or connection; and he expresses this universal fact by a very simple formula; and calling this also a principle, he solves every question with ease and neatness, by reducing it to the investigation of those velocities. In this way he has written a complete system of dynamics, to which he gives the title of *Mechanique Analytique*, full of the most ingenious and elegant solutions of very interesting and difficult problems; and all this without drawing a line or figure, but accomplishing the whole by algebraic operations.

But this is not teaching mechanical philosophy; it is merely employing the reader in algebraic operations, each of which he perfectly understands in its quality of an algebraic or arithmetical operation, and where he may have the fullest conviction of the justness of his procedure. But all this may be (and, in the hands of an expert algebraist, it generally is), without any notions, distinct or indistinct, of the things, or the processes of reasoning that are represented by the symbols made use of. It is precisely like the occupation of a banker's clerk when he carries his eye up and down the columns of pounds shillings and pence, calculates the compound interest, reversionary values, &c.

139.

It

Conclusion.
Disadvantages of the symbolical method.

It were well if this were all, although it greatly diminishes the pleasure which an accomplished mathematician might receive; but this total absence of ideas exposes even the most eminent analyst to frequent risks of paralogism and physical absurdity. Euler, who was perhaps the most expert algebraist of the last century, making use of the Newtonian theorem for ascertaining the motion of a body impelled along a straight line AC (fig. 24.) by a centripetal force, by comparing it with the motion in an ellipse, of which the shorter axis was diminished till it vanished altogether, expresses his surprise at finding, that when he computes the place of the body for a time subsequent to that of its arrival at C, the body is back again, and in some place between C and A; in short, that the body comes back again to A, and plays backward and forward. He says that this is somewhat wonderful, and seems inconsistent with sound reason: "*sed analysi magis fidentum.*" It must be so. And he goes on to another problem.

In like manner Mr Maupertuis, an accomplished man and good philosopher and geometer, finding the symbol MVS, or the quantity of matter, multiplied by the velocity and by the distance run over during the action, always present itself to him as a mathematical minimum in the actions of bodies on each other; he was amused by the observation, and presumed that there was some reason for it in the nature of things. Finding that it gave him very neat solutions of many elementary problems in dynamics, he thought of trying whether it would assist him in accounting for the constant ratio of the sines of incidence and refraction; he found that it gave an immediate and very neat solution. This problem had, before his time, occupied the minds of Des Cartes and Fermat. Each of these gentlemen solved the problem by saying, that the light did not take the *shortest* way from a point in the air to a point under water, but the *easiest* way, in conformity with the acknowledged economy of nature and consummate wisdom of its adorable Author. But how was this the easiest way, the course that economised the labour of nature? One of these gentlemen proved it to be so, if light move faster in air than in water; the other proved it to be so, if light move faster in water than in air. Both could not be right. Maupertuis was convinced that he had discovered what it was that nature was so chary of, and grudged to waste—it was MVS! Therefore MVS can mean nothing but labour; nothing but natural exertion, mechanical action; therefore MVS is the proper measure of action. He kept this great discovery a profound secret; and, being President of the Royal Academy of Berlin, he proposed for the annual prize question, "Are the laws of motion necessary or contingent truths?" He could not compete for the

prize, by the laws of the Academy; but before the time of decision, he published at Paris his *Dissertation on the Principle of the least Action*; in which he pointed out the singular fact of MVS being always a minimum; and therefore, in fact, the object of nature's economical care. He solved a number of problems by making the minimum state of $\frac{fv^2}{m}$ a condition of the problems; and,

to crown the whole, shewed that the laws of motion which obtain in the universe could not be but what they are, because this economy was worthy of infinite wisdom; and therefore any other laws were impossible. The reputation of Maupertuis was already established as a good mathematician and a worthy and amiable man, and he was a favourite of Frederic. The principle of least action became a mode; and it drew attention for some time, till it went out of fashion. It is no mechanical principle, but a necessary mathematical truth, as any person must see who recollects that v is the same with s , and that f is the same with $m \cdot v$.

To avoid such paralogisms and such whims, we are convinced that it is prudent to deviate as little as possible in our discussions from the *geometrical method*. This has surely the advantage of keeping the real subject of discussion close in view; for motion includes the notion of lines, with all their qualities of magnitude and position. It is needless to take a representative when the original itself is in our hands, and affords a much more comprehensible object than one of its abstract qualities, mere magnitude. Let any person candidly compare the lunar theory by Mayer or Euler with that by its illustrious inventor Sir Isaac Newton, and say which of the two is most luminous and most pleasing to the mind. No person will deny that these latter performances are incomparably more adapted to all practical purposes, and lead to corrections which it would be extremely difficult and tedious to investigate geometrically; but it must be acknowledged, at the same time, that *till this be done*, we have no idea whatever of the deviation of the track which this correction ascertains from the path which the moon would follow, independent of the disturbance expressed by the correction. In like manner, Dan. Bernoulli, by mixing as much as possible the linear method with the algebraic, in his dissertations on musical chords, made the beautiful discovery of the secondary trochoids, and demonstrated the co-existence of the harmonic sounds in a full musical note. Let the accomplished mathematician push forward our knowledge of dynamics by the employment of the symbolical analysis; but let him be followed as close as possible by the geometer, that we may not be robbed of ideas, and that the student may have light to direct his steps. But,—*manum e tabulâ.*

Conclusion.

Great advantages of the geometrical method.

D Y N

D Y N

DYNAMOMETER, an instrument for ascertaining the relative muscular strength of men and other animals. That it would be desirable to know our relative strengths at the different periods of life, and in different states of health, will hardly be denied; and there can be no doubt but that it would be highly useful to have a portable instrument by which we could ascertain the relative strength of horses or oxen intended for the

plough or the waggon. Such an instrument was invented, many years ago, by Graham, and improved by Defaguliers; but being constructed of wooden work it was too bulky to be portable, and therefore it was limited in its use.

M. Leroy of the Academy of Sciences at Paris constructed a much more convenient Dynamometer than Graham's, consisting of a metal tube, 10 or 12 inches

3 Z 2

in

Dynamometer.

Dynamometer.

Dynamometer.

in length, placed vertically on a foot like that of a candlestick, and containing in the inside a spiral spring, having above it a graduated shank terminating in a globe. This shank, together with the spring, sunk into the tube in proportion to the weight acting upon it, and thus pointed in degrees the strength of the person who pressed on the ball with his hand.

This was a very simple construction, and, we think, a good one; but it did not satisfy Buffon and Gueneau. These two philosophers wished not merely to ascertain the muscular force of a finger or a hand, but to estimate that of each limb separately, and of all the parts of the body. They therefore employed M. Regnier to contrive a new *dynamometer*; and the account which he gives* of his attempts to fulfil their wishes is calculated to enhance the difficulty of the enterprise. The instrument, however, which he constructed, is not such as appears to us to have required any uncommon skill in mechanics, or any very great stretch of thought. It consists chiefly of an elliptical spring, 12 inches in length, rather narrow, and covered with leather that it may not hurt the fingers when compressed by the hands. This spring is composed of the best steel well welded and tempered, and afterwards subjected to a stronger effort than is likely to be ever applied to it either by men or animals, that it may not lose any of its elasticity by use.

The effects of this machine are easily explained. If a person compresses the spring with his hands, or draws it out lengthwise by pulling the two extremities in contrary directions, the sides of the spring approach towards each other; and it has an apparatus (we do not think a very simple one) appended to it, consisting of an index and semicircular plate, by which the degree of approach, and consequently of effort, employed, is ascertained with great accuracy. The author gives a tedious description of other appendages, by means of which

horses or oxen may be employed to compress the spring. ^{Dysentery.} But as any mechanic may devise means for this purpose, we do not think it worth while to transcribe that description. The English reader will find a full account of the whole apparatus in the 4th number of the very valuable miscellany intitled *The Philosophical Magazine*. The principle of the contrivance consists in the elliptical spring, of which we confess ourselves unable to perceive the superiority to the spiral spring of M. Leroy, though the author sees it very clearly.

DYSENTERY. See *MEDICINE-Index*, Encycl.—For the cure of this disease we have the following simple prescription by Dr Perkins and Dr B. Lynde Oliver, of the State of Massachusetts in North America.

Saturate any quantity of the best vinegar with common marine salt; to one large table-spoonful of this solution add four times the quantity of boiling water; let the patient take of this preparation, as hot as it can be swallowed, one spoonful once in half a minute until the whole is drank: this for an adult. The quantity may be varied according to the age, size, and constitution of the patient. If necessary, repeat the dose once in six or eight hours. Considerable evacuations I conceive (says Dr Parkins) to be not only unnecessary, but injurious, as they serve to debilitate and prolong the disease. A tea of plantain, or some other cooling simple drink, may be useful; and if a thirst for cyder be discovered, it may be gratified. Carefully avoid keeping this preparation in vessels partaking of the qualities of lead or copper, as the poison produced by that means may prove dangerous.

The success of the remedy depends much on preparing and giving the dose as above directed.—The simplicity of this treatment renders it the more valuable, as all persons have it in their power to avail themselves of its use.

Dr Perkins says, that he has found it useful in agues; diarrhœas, and the yellow fever.

* *Journal de l'Ecole Polytechnique*, v. 2.

E.

E A R

E A R

Earth.

EARTH, in chemistry. See *CHEMISTRY-Index* in this Supplement.

EARTH, in astronomy and geography. See *Encyclopædia*.

EARTH, in ancient philosophy, one of the elements, the substance of which this globe is composed. To ascertain the density of that substance, many experiments have been made; but perhaps none more ingenious than those of Mr Cavendish, which are detailed at full length in Part II. of the Transactions of the Royal Society of London for 1798. They were projected by the late Rev. John Michell, F. R. S. but he did not live to carry them into effect. After his death, the apparatus came to the Rev. F. J. H. Wollaston, Jacksonian Professor at Cambridge, who transferred them to Mr Cavendish. The apparatus contrived for making sensible the attraction of small quantities of matter, and which has been improved by Mr Cavendish, is very simple: it

consists of a wooden arm 6 feet long, suspended by the middle in an horizontal position by a slender wire 40 inches long; to each extremity is hung a leaden ball about two inches in diameter; and the whole is inclosed in a wooden case to defend it from the wind. ^{Earth.}

As no more force is required to turn this balance on its centre than is necessary to twist the slender suspending wire, the smallest degree of attraction of a leaden weight or weights, a few (eight) inches in diameter, brought near to the small suspended ball or balls of the balance, will be sufficient to move it sensibly aside.

To determine from hence the density of the earth, all that is necessary is, to ascertain what force is required to draw the arm aside through a given space, and then to have recourse to calculation.

To prevent any disturbance from currents that might be produced within the box that contained the balance, by even the difference of temperature that might be occasioned

Fig. 1.

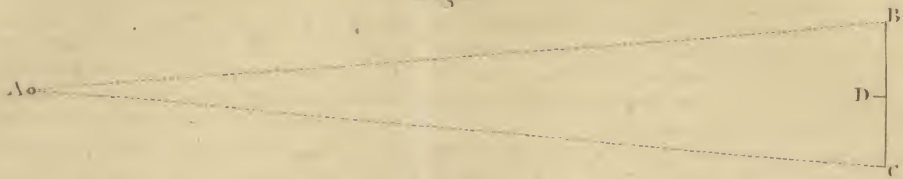


Fig. 2.

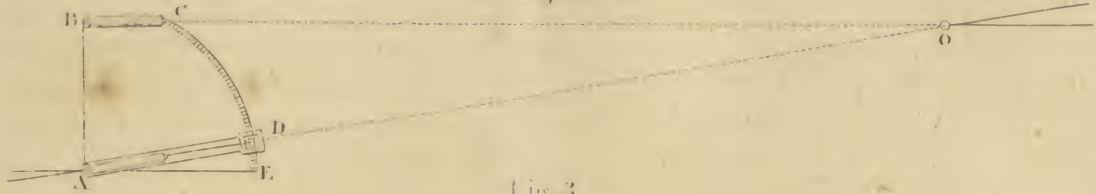
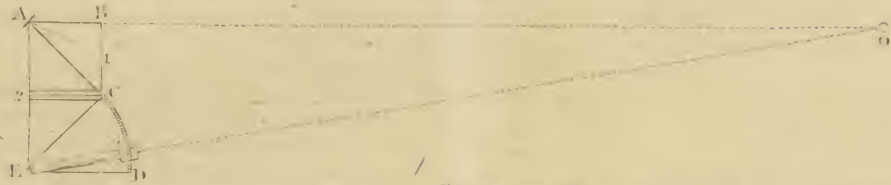


Fig. 3.



DYNAMICS

Fig. 1.

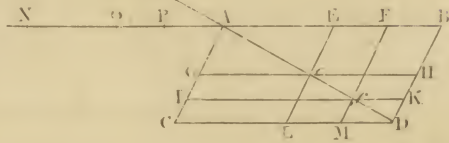


Fig. A.

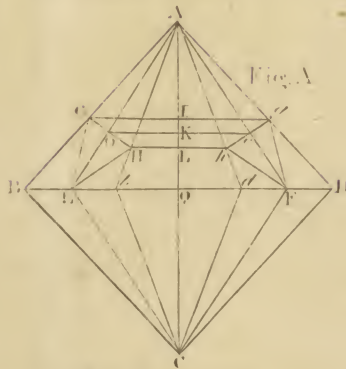


Fig. 2.

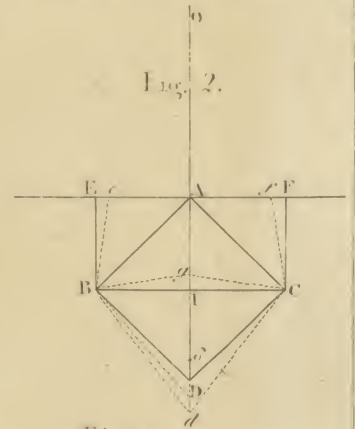


Fig. 3.

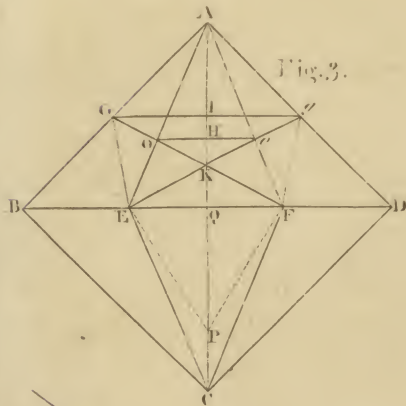


Fig. 5.

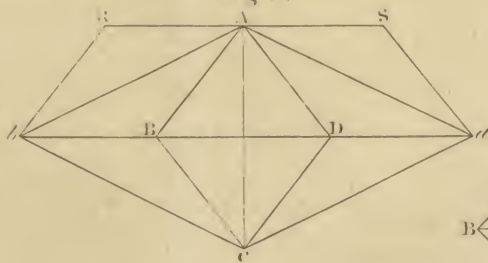


Fig. 4.

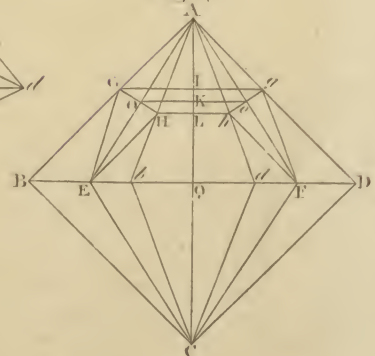


Fig. 6.

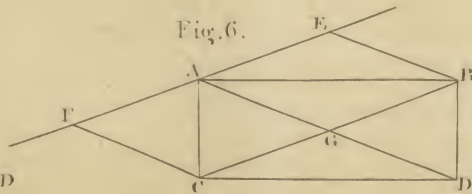


Fig. 7. N° 2.

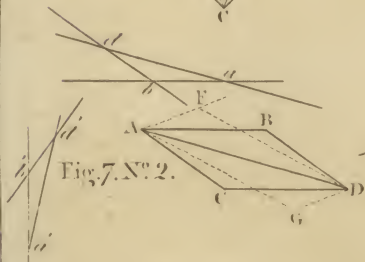
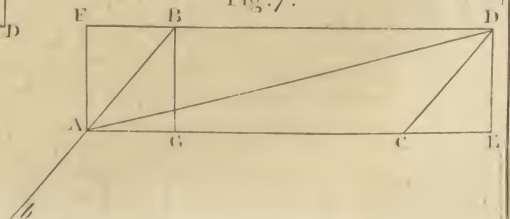
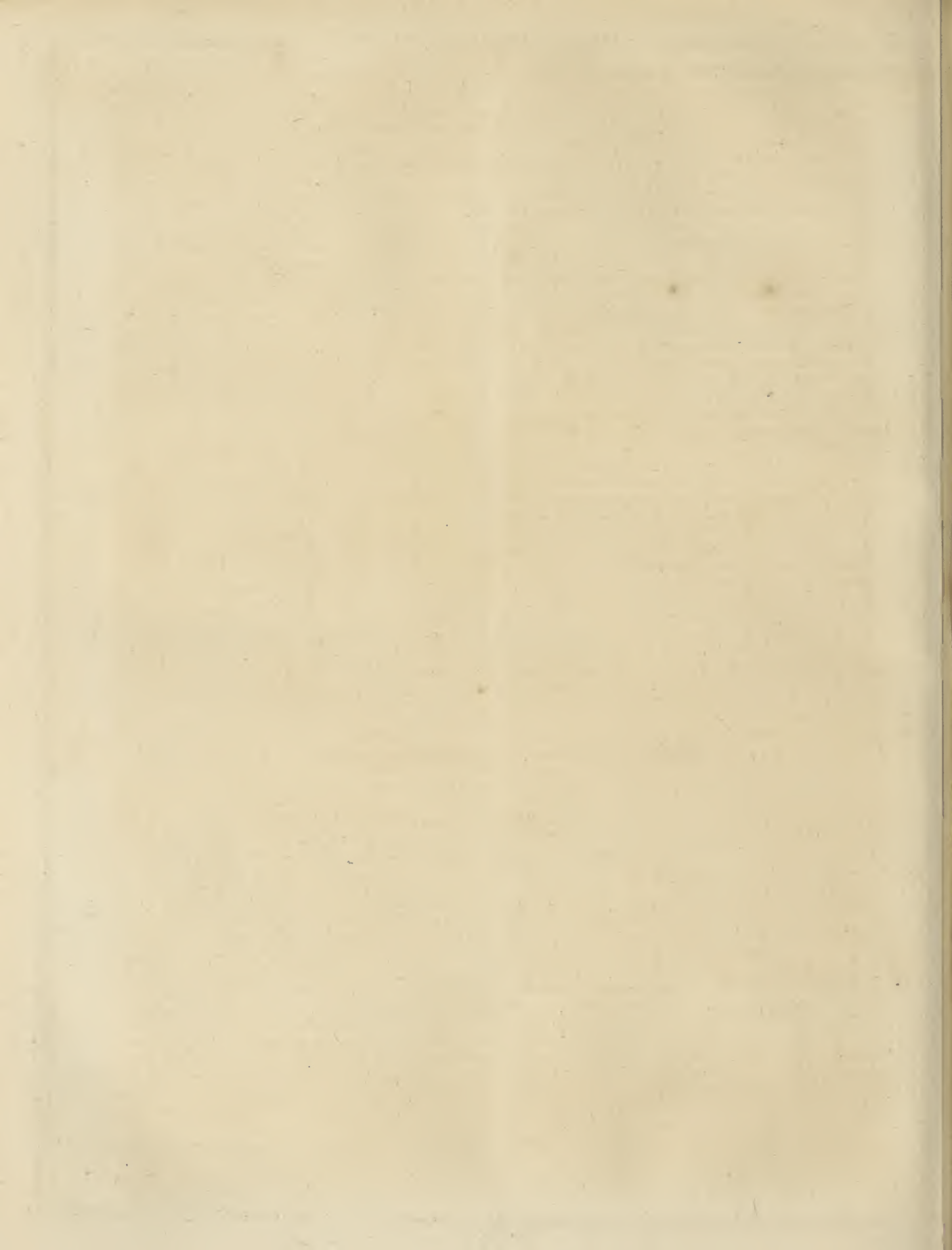
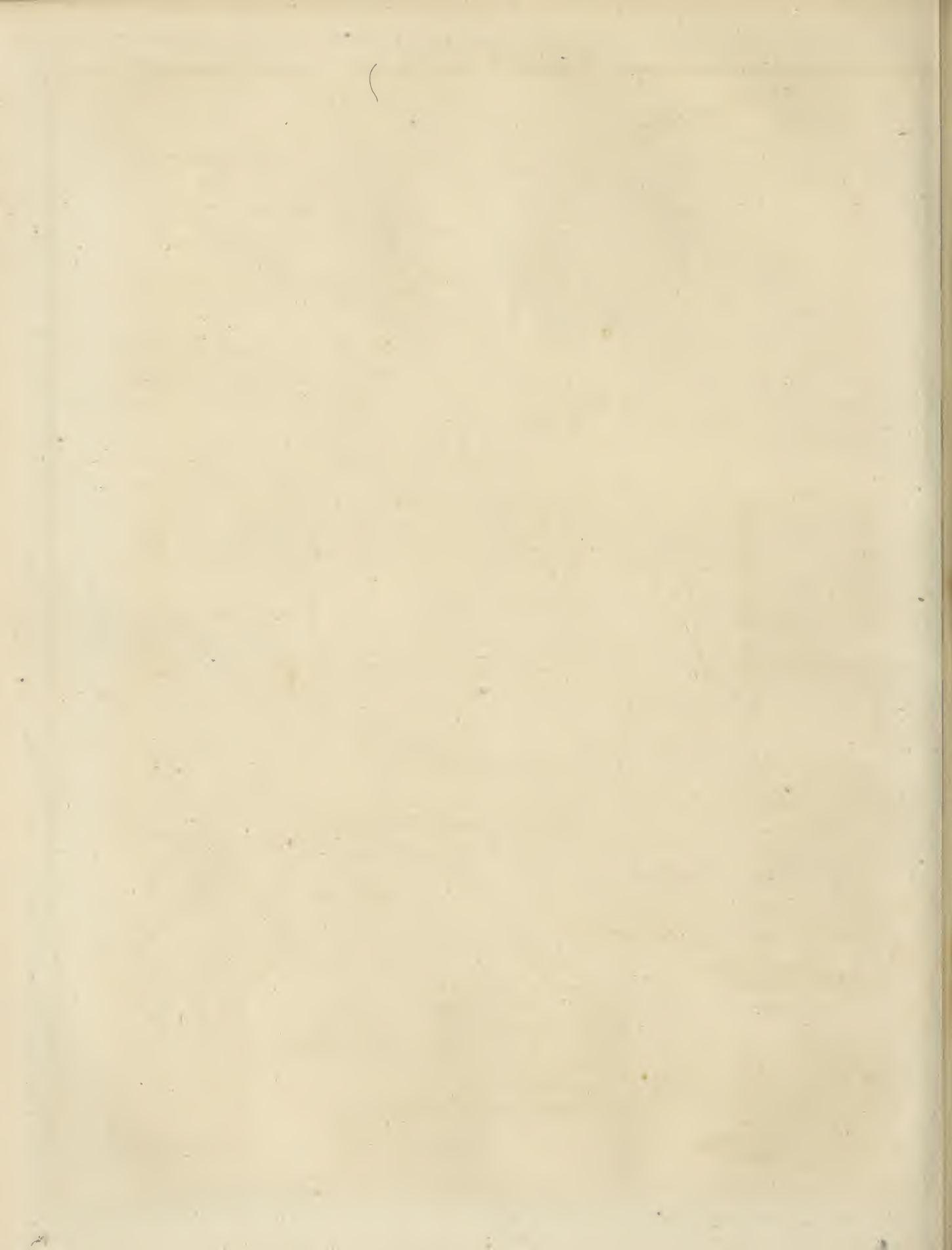
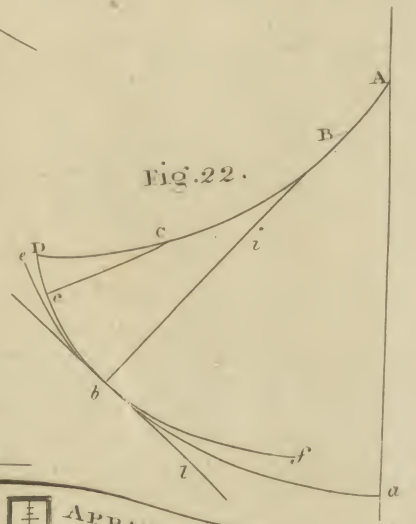
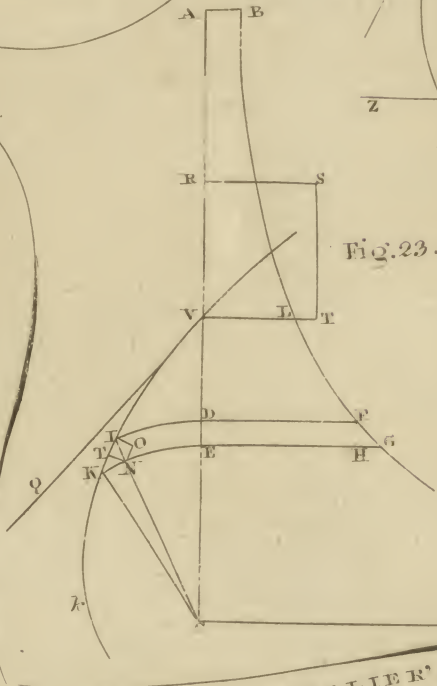
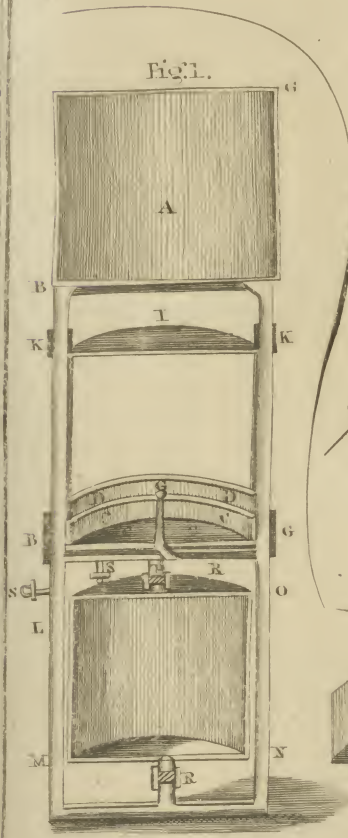
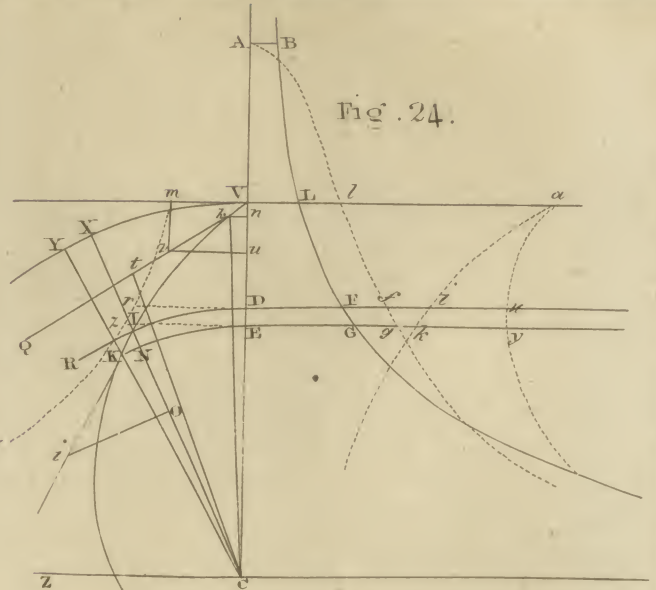
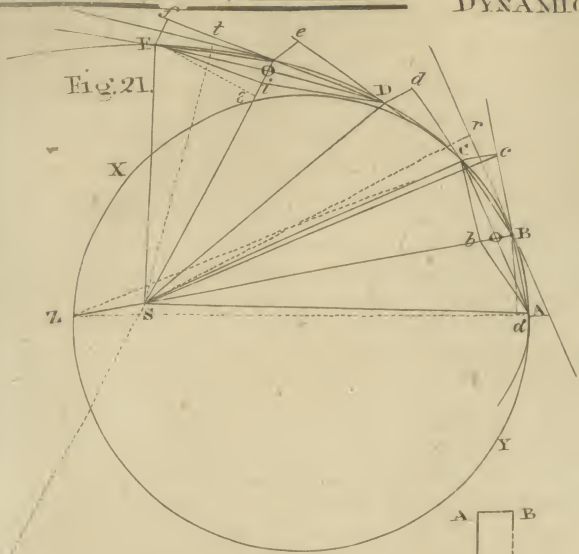


Fig. 7.

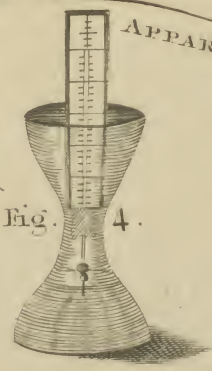
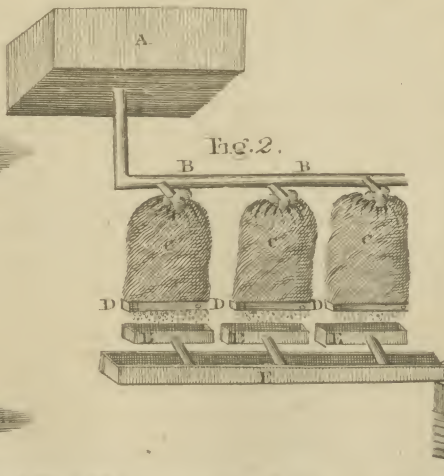
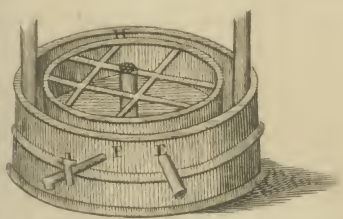


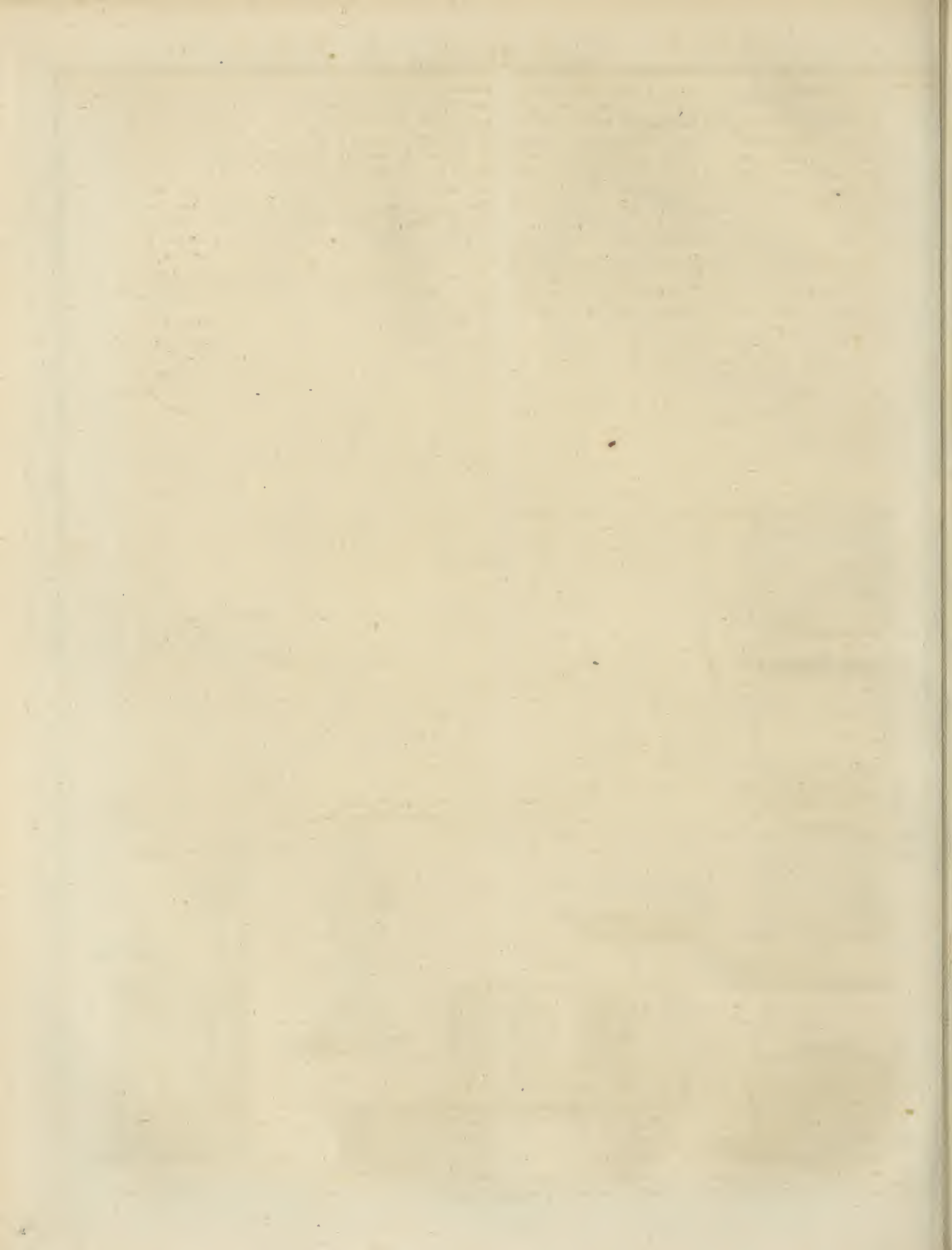






COLLIER'S APPARATUS.





Earth.

occasioned by heat being communicated by the bodies of the experimenters to one side of it more than another, it was supported in the middle of a close room; the operators, from adjoining apartments, viewed the operation through holes in the wall by means of telescopes; and the apparatus had a strong light thrown upon its two ends (an opening being left at each end of the box for the purpose) by means of two lamps, also in the adjoining apartments, the rays from which were likewise made to pass through the holes formed in the wall.

The two large balls were suspended from a beam near the ceiling, which could be moved in an horizontal direction, by means of a string and pulley, so as to be brought near to the small balls of the balance, or made to recede again, without requiring any person to be in the room.

From this description it will be easily seen, that on the two large balls being brought near to the two small ones, but on opposite sides of each, that their forces may not counteract each other—the small suspending wire of the balance must be twisted by the movements of the arms, occasioned by attraction, which carries the small towards the large balls; and that the wire, endeavouring to untwist itself, will again in its turn carry the small balls away from the large ones. Vibrations are thus occasioned, which would continue a long time before the small balls would settle between the first point of rest and the large balls: but it is not necessary to wait for this; an ivory scale at each end of the balance enables the experimenters, by means of their telescopes, to see the two extreme divisions to which the small balls move in their vibrations, and thus to determine the middle point. The time necessary for each vibration is also noticed.

A full account of these experiments, and of the calculations founded on them, would be little interesting to the great majority of our readers. We shall therefore only mention the result. By a mean of the experiments the density of the earth comes out 5.48 times greater than that of water.

By the experiments made by Dr Maskelyne on the attraction of the hill Schiehallien, the density of the earth was computed to be only $4\frac{1}{2}$ times that of water. The difference of result, therefore, is almost one-fifth, which no doubt must lessen our confidence in either set of experiments, or in the principle on which they were devised.

EARTH WORM (see *LUMBRICUS*, *Encycl.*), is an animal which occasions such destruction in gardens, by gnawing the tender roots of shrubs and plants, that various methods have been proposed for remedying this evil. One of the latest, and that which promises to prove the most successful, is given by M. SOCOLOFF in the fifth volume of the *New Transactions of the Imperial Academy of Sciences at Petersburg*. As the destructive power of quick lime, heightened by a fixed alkali, which corrodes or dissolves all the tender parts of animals, has been long known, it occurred to our author that this mixture would be the best means for accomplishing the object which he had in view. He therefore took three parts of quicklime, newly made, and two parts of a saturated solution of fixed alkali in water, and thence obtained a somewhat milky liquor sufficiently caustic, highly hostile and poisonous to earth-worms and other small animals; for as soon as it touched any part of their bodies, it occasioned in them vio-

Earth,
Eau de luce.

lent symptoms of great uneasiness. If this liquor be poured into those holes in which the earth-worms reside under ground, they immediately throw themselves out as if driven by some force; and, after various contortions, either languish or die. If the leaves of plants or fruit-trees frequented by the voracious caterpillars, which are so destructive to them, be sprinkled over with this liquor, these insects suddenly contract their bodies and drop to the ground. For though Nature has defended them tolerably well by their hairy skins from any thing that might injure their delicate bodies, yet as soon as they touch with their feet or mouths leaves which have been moistened by this liquor, they become as if it were stupified, instantly contract themselves, and fall down.

With regard to plants or corn, these sustain no injury from the liquor, because it has no power over the productions of the vegetable kingdom, as our author has fully learned from experience; or if any hurt is to be suspected, all the danger will be removed by the first shower that falls. This liquor may be procured in abundance in every place where lime is burnt. If the lime be fresh, one part of it infused into about seventy parts of common water will produce real lime-water. The want of the fixed alkali may be supplied by boiling wood-ashes in water, and thickening the ley by evaporation.

This liquor might be employed also to kill bugs and other domestic insects; but on account of its strong lixivious smell, M. Socoloff thinks it could not be used with safety in houses that are inhabited. Nothing, however, more speedily or more effectually destroys bugs, as our author says he has repeatedly experienced, than the oily pickle that remains in casks in which salted herrings have been packed.

EAU DE LUCE, a fragrant alkaline liquor which was some years ago in great repute, especially among the fair sex, and of which the leading perfection is, that it shall possess and retain a milky opacity.

Mr Nicholson, in the second number of his valuable journal, tells us, that being informed by a philosophical friend, that the usual recipes for making this compound (see *CHEMISTRY*, *Encycl.* n^o 1037.) do not succeed, and that the use of mastic in it has hitherto been kept a secret, he made the following trials to procure a good eau de luce.

One dram of the rectified oil of amber was dissolved in four ounces of the strongest ardent spirit of the shops; its specific gravity being .840 at 60 degrees of Fahrenheit. A portion of the clear spirit was poured upon a larger quantity of fine powdered mastic than it was judged could be taken up. This was occasionally agitated without heat; by which means the gum resin was for the most part gradually dissolved. One part of the oily solution was poured into a phial, and to this was added one part of the solution of mastic. No opacity or other change appeared. Four parts of strong caustic volatile alkali were then poured in, and immediately shaken. The fluid was of a dense opaque white colour, affording a slight ruddy tinge when the light was seen through a thin portion of it. In a second mixture, four parts of the alkali were added to one of the solution of mastic; it appeared of a less dense and more yellowish white than the former mixture. More of the gum resinous solution was then poured in; but it still appeared less opaque than that mixture. It was ruddy

Eau de luce
Ecliptic.

ruddy by transmitted light. The last experiment was repeated with the oily solution instead of that of mastic. The white was much less dense than either of the foregoing compounds, and the requisite opacity was not given by augmenting the dose of the oily solution. No ruddiness nor other remarkable appearance was seen by transmitted light. These mixtures were left at repose for two days; no separation appeared in either of the compounds containing mastic; the compound consisting of the oily solution and alkali became paler by the separation of a cream at the top.

It appears, therefore, that the first of these three mixtures, subject to variation of the quantity of its ingredients, and the odorant additions which may be made, is a good eau de luce.

In a subsequent number of the same Journal, we have the following recipe by one of the author's correspondents, who had often proved its value by experience. "Digest ten or twelve grains of the whitest pieces of mastic, selected for this purpose and powdered, in two ounces of alcohol; and, when nearly dissolved, add twenty grains of elemi (See AMYRIS, *Encycl.*). When both the resins are dissolved, add ten or fifteen drops of rectified oil of amber, and fifteen or twenty of essence of bergamot: shake the whole well together, and let the fæces subside. The solution will be of a pale amber colour. It is to be added in very small portions to the best aqua ammoniæ puræ, until it assumes a milky whiteness, shaking the phial well after each addition, as directed by Macquer. The strength and causticity of the ammoniac are of most essential consequence. If, upon the addition of the first drop or two of the tincture, a dense opaque coagulated precipitate is formed, not much unlike that which appears on dropping a solution of silver into water slightly impregnated with common salt, it is too strong, and must be diluted with alcohol. A considerable proportion of the tincture, perhaps one to four, ought to be requisite to give the liquor the proper degree of opacity."

EAVES BOARD, or EAVES-LATH, a thick feather-edged board, usually nailed round the eaves of a house for the lowermost tiles, slate, or shingles, to rest upon.

ECLIPSAREON, an instrument invented by Mr Ferguson for shewing the phenomena of eclipses; as their time, quantity, duration, progress, &c.

ECLIPTIC. See *Encycl.* both under ECLIPTIC and in *ASTRONOMY-Index*. It was observed in *ASTRONOMY, Encycl.* n^o 407. that the obliquity of the ecliptic has been found gradually to decrease. This was observed, among others, by *La Lande*, who, in the third edition of his astronomy, reckoned the secular diminution of this obliquity at 50 seconds. From a new examination, however, of ancient observations, he has since found reason to estimate it at only 36 seconds; but whether this be perfectly accurate, is very doubtful. The mean obliquity was determined for the 1st of January 1793, with circular instruments, by *Mechain* at Barcelona, and *Piazzi* at Palermo, to be 23° 27' 53".3. Yet the observation of the summer solstice of 1796, by *Mechain* and *Le Français*, gave 11 seconds more; which was justly considered as a perplexing circumstance. But, as one of the ablest of our literary journalists observes, might not this difference arise from the uncertainty of our tables of refraction, as affected by the hygroscopic variations of the atmosphere?

ECLIPTIC Bounds, or Limits, are the greatest distances

from the nodes at which the sun or moon can be eclipsed, namely, near 18 degrees for the sun, and 12 degrees for the moon.

EDYSTONE ROCKS, so remarkable for the light-house built on them, obtained their name from the great variety of contrary sets of the tide or current in their vicinity. They are situated nearly S. S. W. from the middle of Plymouth Sound, according to the true meridian. The distance from the port of Plymouth is nearly 14 miles, and from the promontory called *Ram-head* about 10 miles. They are almost in the line, but somewhat within it, which joins the Start and the Lizard points; and as they lie nearly in the direction of vessels coasting up and down the channel, they were necessarily, before the establishment of a light house, very dangerous, and often fatal to ships under such circumstances. Their situation, likewise, with regard to the Bay of Biscay and Atlantic ocean, is such, that they lie open to the swells of the Bay and ocean from all the south-western points of the compass: which swells are generally allowed by mariners to be very great and heavy in those seas, and particularly in the Bay of Biscay. It is to be observed, that the soundings of the sea from the south-westward toward the Edystone are from 80 fathoms to 40, and everywhere till you come near the Edystone the sea is full 30 fathoms in depth; so that all the heavy seas from the south-west come uncontrouled upon the Edystone rocks, and break on them with the utmost fury.

The force and height of these seas is increased by the circumstance of the rocks stretching across the Channel, in a north and south direction, to the length of above 100 fathoms, and by their lying in a sloping manner toward the south-west quarter. This *sliving* of the rock, as it is technically called, does not cease at low water, but still goes on progressively; so that, at 50 fathoms westward, there are 12 fathoms water; nor do they terminate altogether at the distance of a mile. From this configuration it happens, that the seas are swelled to such a degree in storms and hard gales of wind, as to break on the rocks with the utmost violence.

The effect of this slope is likewise sensibly felt in moderate, and even in calm weather; for the libration of the water, caused in the Bay of Biscay in hard gales at south-west, continues in those deep waters for many days, though succeeded by a calm; insomuch, that when the sea is to all appearance smooth and even, and its surface unruffled by the slightest breeze, yet those librations still continuing, which are called the *ground-swell*, and meeting the slope of the rocks, the sea breaks upon them in a frightful manner, so as not only to obstruct any work being done on the rock, but even the landing upon it, when, figuratively speaking, you might go to sea in a walnut shell. A circumstance which still farther increases the difficulty of working on the rock is, there being a sudden drop of the surface of the rock, forming a step of about four and a half, or five feet high; so that the seas, which in moderate weather come swelling to this part, meet so sudden a check that they frequently fly to the height of 30 or 40 feet.

Notwithstanding these difficulties, it is not surprising that the dangers to which navigators were exposed by the Edystone rocks should make a commercial nation desirous of having a light-house on them. The wonder is, that any one should be found hardy enough to undertake the building. Such a man was first found

Ecliptic,
Edystone,
Light-house.

*Smeaton's
Account of
the Edystone
Light-house.*

Edystone. in the person of *Henry Winstanley* of Littlebury in Essex, Gent. who, in the year 1696, was furnished by the master, wardens, and assistants, of the Trinity-house of Deptford-strond with the necessary powers to carry the design into execution.

Mr Winstanley had distinguished himself in a certain branch of mechanics, the tendency of which is to raise wonder and surprize. He had at his house at Littlebury a set of contrivances, such as the following: Being taken into one particular room of his house, and there observing an old slipper carelessly lying on the floor; if, as was natural, you gave it a kick with your foot, up started a *ghost* before you. If you sat down in a certain chair, a couple of arms would immediately clasp you in, so as to render it impossible to disentangle yourself till your attendant set you at liberty. And if you sat down in a certain arbour by the side of a canal, you were forthwith sent out *afloat* to the middle of the canal, from whence it was impossible for you to escape till the manager returned you to your former place.— Whether those things were shewn to strangers at his house for money, or were done by way of amusement to those that came to visit the place, is uncertain, as Mr Winstanley is said to have been a man of some property; but it is at least certain, that he established a place of public exhibition at Hyde Park-corner, called *Winstanley's water-works*, which were shewn at stated times at one shilling each person. The particulars of those water-works are not now known; but, according to the taste of the times, we must naturally suppose a great variety of *jets d'eau*, &c.

These particulars are at present of no other importance than that they serve to give a sketch of the talents and turn of mind of the original undertaker, and to account for the whimsical kind of buildings which he erected on the Edystone; from the design of which, it seems as if it were not sufficient for his enterprising genius to erect a building on the spot, where, of all others, it was least likely to stand unhurt; but that he would also give it an elevation, in appearance the most liable to subject it to damage from the violence of the wind and waves.

This ingenious man entered upon his great undertaking in 1696, and completed it in something more than four years. The first summer was occupied with making 12 holes in the rock, and in fastening 12 great irons, which were to hold the work that was afterward to be done. The next summer was spent in making a solid body, or round pillar, 12 feet high and 14 feet in diameter. In the third year, the aforesaid pillar or work was made good at the foundation, from the rock, to 16 feet in diameter; and all the work was raised, which, to the vane, was 80 feet high. Being all finished, with the lantern, and all the rooms that were in it, we “ventured (says Mr Winstanley) to lodge there soon after midsummer, for the greater dispatch of this work: but the first night the weather came bad, and so continued, that it was eleven days before any boats could come near us again; and not being acquainted with the height of the seas rising, we were almost all the time drowned with wet, and our provisions in as bad a condition, though we worked night and day, as much as possible, to make shelter for ourselves.”

Mr Winstanley, however, succeeded in setting up the light on the 14th of November in that year (1698); but he was detained till within three days of Christmas

before he could return to shore, being almost at the last extremity for want of provisions.

Edystone.

In the fourth year, observing the effects that the sea produced on the house, burying the lantern at times, although more than 60 feet high, Mr Winstanley encompassed the aforesaid building early in the spring with a new work of four feet thickness from the foundation, making all solid for near 20 feet high; and taking down the upper part of the first building, and enlarging every part in its proportion, he raised it 40 feet higher than it was at first: Yet, he observes, “the sea, in times of storms, flies in appearance *one hundred feet above the vane*, and at times doth cover half the side of the house and the lantern as if it were under water.”

No material occurrences concerning this building happened till November 1703, when the fabric, needing some repairs, Mr Winstanley went down to Plymouth to superintend the work. And “we must not wonder (says Mr Smeaton), if, from the preceding accounts of the violence of the seas, and the structure of the light-house, the common sense of the public led them to suppose this building would not be of long duration. The following is an anecdote which I received to the same effect from so many persons that I can have no doubt of the truth of it: Mr Winstanley being among his friends previous to his going off with his workmen on account of those reparations, the danger being intimated to him, and that one day or other the light-house would certainly be overlet; he replied, “He was so very well assured of the strength of his building, he should only wish to be there in the greatest storm that ever blew under the face of the heavens, that he might see what effect it would have on the structure.”—It happened that Mr Winstanley was but too amply gratified in this wish; for while he was there with his workmen and light-keepers, that dreadful storm began which raged most violently on the 26th of November 1703, in the night; and of all the accounts of the kind which history furnishes us with, we have none that has exceeded this in Great Britain, or was more injurious or extensive in its devastation. The next morning, November 27th, when the violence of the storm was so much abated that it could be seen whether the light-house had suffered by it, nothing appeared standing, but, upon a nearer inspection, some of the large irons by which the work was fixed upon the rock; nor were any of the people, or any of the materials of the building, ever found afterwards, save only part of an iron chain, which had got so fast jammed into a chink of the rock, that it could never afterwards be disengaged till it was cut out in the year 1756.”

Thus perished Mr Winstanley, together with his building: but so great was the utility of that building while it stood, that the public could not fail to be desirous of having another in its place. Accordingly, in 1706, an act of parliament of the 4th of Queen Anne was passed, for the better enabling the master, &c. of the Trinity-house of Deptford-strond to rebuild the same. By this act, the duties payable by shipping passing the light-house were vested in the corporation of the Trinity-house, who were empowered to grant a lease to such undertaker or undertakers as they should approve. In consequence, they agreed with a Captain *Lovel* or *Lovet* for a term of 99 years, commencing from the day on which a light should be exhibited, and continuing so long as that exhibition should last during

Edyſtone. the ſaid term. On this foundation Captain Lovet engaged Mr John Rudyerd to be his engineer or architect and ſurveyor.

It does not appear that Mr Rudyerd was bred to any mechanical buſineſs or ſcientific profeſſion, being at that time a ſilk mercer on Ludgate-hill; nor is it known that, in any other inſtance, he had diſtinguiſhed himſelf by any mechanical performance before or after. His want of perſonal experience, however, was in a degree aſſiſted by Mr Smith and Mr Norcutt, both ſhipwrights in the King's yard at Woolwich.

It is not, as Mr Smeaton obſerves, very material in what way this gentleman became qualified for the execution of his work; it is ſufficient that he directed the performance in a maſterly manner, and ſo as perfectly to answer the end for which it was intended. He ſaw the errors in the former building, and avoided them; inſtead of a polygon he choſe a circle for the outline of his building, and carried up the elevation in that form. His principal aim appears to have been *uſe* and *ſimplicity*; and indeed, in a building ſo ſituated, the former could hardly be acquired in its full extent without the latter. He ſeems to have adopted ideas the very reverſe of his predeceſſor; for all the unwieldy ornaments at top, the open gallery, the projecting cranes, and other contrivances, more for ornament and pleaſure than uſe, Mr Rudyerd laid totally aſide. He ſaw, that how beautiful ſoever ornaments might be in themſelves, yet when they are improperly applied and out of place, by affecting to ſhew a taſte, they betray ignorance of its firſt principle, *judgment*; for whatever deviates from propriety is erroneous, and at beſt inſipid.

It is impoſſible for us to give an accurate account of the conſtruction of Mr Rudyerd's light-houſe. We can only ſay, in general terms, that it was altogether built of wood; for the courſes of moorſtone, which Mr Rudyerd, adverting to the maxim, that *weight* is beſt reſiſted by *weight*, introduced into the ſolid part of his building, muſt be conſidered as being of the nature of ballaſt; the weight of theſe amounted to above 270 tons. The main column of the building conſiſted of one ſimple figure, being an elegant fruſtum of a cone, unbroken by any projecting ornament, or any thing on which the violence of the ſtorms could lay hold; meaſuring, excluſively of its ſloping foundation, 22 feet and eight inches on its largeſt circular baſe; 61 feet high above that circular baſe; and 14 feet and three inches in diameter at the top: ſo that the circular baſe was ſomewhat greater than one-third of the total height, and the diameter at the top was leſs than two-thirds of the baſe at the greateſt circle. On the flat roof of this main column, as a platform, Mr Rudyerd fixed his lantern, which was an octagon of ten feet and ſix inches diameter externally. The mean height of the window-frames of the lantern above the balcony floor was nearly nine feet; ſo that the elevation of the centre of the light above the high-eſt ſide of the baſe was 70 feet; that is, lower than the centre of Mr Winſtanley's ſecond lantern by ſeven feet, but higher than that of his firſt by 24 feet. The width of Mr Rudyerd's lantern was, however, nearly the ſame as that of Mr Winſtanley's ſecond: but inſtead of the towering ornaments of iron-work, and a vane that roſe above the top of the cupola no leſs than 21 feet, Mr Rudyerd judiciously contented himſelf with finiſhing his building with a round ball of two feet and three inches diameter, which termi-

Edyſtone. nated at three feet above the top of his cupola. The whole height of Mr Rudyerd's light-houſe, from the loweſt ſide to the top of the ball, was 92 feet, on a baſe of 23 feet and four inches, taken at a medium between the high-eſt and loweſt part of the rock that it covered. The whole building was completed in the year 1709, three years from its commencement.

This great work, after having braved the elements for forty-fix years, was burnt to the ground in 1755. On the 2d of December of that year, when the light-keeper, then on the watch, went, about two o'clock in the morning, into the lantern, to ſnuff the candles according to cuſtom, he found it in a ſmoke; and in ſpite of all that he and his companions could do, the whole edifice was on fire in the compaſs of little more than eight hours, and in a few days was burnt to its foundation. The three light-men were with much difficulty got on ſhore, when one of them immediately ran off, and has never ſince been heard of. Another, who had been dreadfully burned by melted lead, of which, according to his own account, he had ſwallowed a quantity, lingered in agony for twelve days, and then expired. His ſtomach being opened, there was found in it a ſolid piece of lead of a flat oval form, which weighed ſeven ounces and five drachms; and thus was verified an aſſertion which, to the ſurgeon and others who attended him, appeared altogether incredible, *viz.* that any human being could live after receiving melted lead into the ſtomach.

On the deſtruction of Mr Rudyerd's light-houſe, Mr Smeaton (ſee SMEATON in this Supplement) was recommended by Lord Maccleſfield, then preſident of the Royal Society, as the fitteſt perſon in England to build another. It was with ſome difficulty that he was able to perſuade the proprietors that a ſtone building, properly conſtructed, would in all reſpects be preferable to one of wood; but having at laſt convinced them, he turned his thoughts to the ſhape which was moſt ſuitable to a building ſo critically ſituated. Reſlecting on the ſtructure of the former buildings, it ſeemed a material improvement to procure, if poſſible, an enlargement of the baſe, without increaſing the ſize of the *waiff*, or that part of the building which is between the top of the rock and the top of the ſolid work. Hence he thought a greater degree of ſtrength and ſtiffneſs would be gained, accompanied with leſs reſiſtance to the acting power. On this occaſion, the natural figure of the waif or bole of a large ſpreading oak occurred to Mr Smeaton.

“ Let us (ſays he) conſider its particular figure.— Connected with its roots, which lie hid below ground, it riſes from the ſurface with a large ſwelling baſe, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter leſs by at leaſt one third, and ſometimes to half its original baſe. From thence, its taper diminiſhing more ſlowly, its ſides by degrees come into a perpendicular, and for ſome height form a cylinder. After that, a preparation of more circumference becomes neceſſary, for the ſtrong inſertion and eſtabliſhment of the principal boughs, which produces a ſwelling of its diameter.— Now we can hardly doubt but that every ſection of the tree is nearly of an equal ſtrength in proportion to what it has to reſiſt; and were we to lop off its principal boughs, and expoſe it in that ſtate to a rapid current of water, we ſhould find it as capable of reſiſting

Edystone resisting the action of the heavier fluid, when divested of the greater part of its clothing, as it was that of the lighter, when all its spreading ornaments were exposed to the fury of the wind: and hence we may derive an idea of what the proper shape of a column of the greatest stability ought to be, to resist the action of external violence, when the quantity of matter is given of which it is to be composed."

The next thing to be considered was, how the blocks of stone could be bonded to the rock, and to one another, in so firm a manner as that not only the whole together, but every individual piece, when connected with what preceded, should be proof against the greatest violence of the sea. For this purpose, cramping was the first idea, but was rejected on account of the great quantity of iron which was necessary, and from the trouble and loss of time which would attend that operation. In its place was substituted the method of dovetailing. From some specimens which Mr Smeaton had seen in Belidor's description of the stone floor of the great sluice at Cherburgh, (where the tails of the upright headers are cut into dovetails for their insertion into the mafs of rough masonry below,) he was led to think, that if the blocks themselves were, both inside and outside, formed into large dovetails, they might be managed so as to lock one another together, being primarily engrafted into the rock; and in the round or entire courses above the top of the rock, they might all proceed from, and be locked to, one large centre stone. These particulars being digested in his own mind, he explained his design by the help of drawings; with which, after mature deliberation, the proprietors were perfectly satisfied; and declared, that the scheme was not only in itself practicable, but, as appeared to them, the only means of doing the business effectually.

During this time Mr Smeaton had never visited the rock on which he was to be employed: he therefore resolved to go to Plymouth early in the spring of 1756, that he might lose no opportunity of viewing it. At Plymouth he met Mr Josias Jessop, to whom he was referred for information and assistance, and who afterwards proved of great service: he was not only an approved workman in his branch as a shipwright, but a competent draughtsman and an excellent modeller; 'in which last (says the author) he was accurate to a great degree: he therefore appeared to be a very fit person to overlook the exact execution of a design given.' Mr Jessop, like others, expressed his doubts that a stone building could stand on the Edystone: but they were removed by the proposed mode of its construction.—As Mr Smeaton was impatient to go to the rock, he seized the first opportunity that seemed to promise any chance of landing on it. On the 2d of April he got within a stone's throw of it, but could not land: on the 5th he was more fortunate; he now landed, and staid on the rock for two hours and a half. This time was employed in taking a general view of the whole. No remains of the house could be perceived either on the rock, or about it, except the greatest part of the iron branches that had been fixed by Mr Rudyerd; and some of the moorstones were discerned lying in the bottom of the gut. Such traces were also observed of the situation of the irons fixed by Mr Winstanley, as to render it no very difficult task to make out his plan, and the position of the edifice; whence it appeared very probable, that Mr Winstanley's building

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was overfet altogether, and that it had torn up a portion of the rock itself, as far as the irons had been fastened in it. With regard to the steps, which were said to have been cut in the rock by Mr Rudyerd, the traces of only five were remaining; these were faintly cut, and without much regularity. It was next tried in what degree the rock was workable; and Mr Smeaton had the satisfaction of finding every thing succeed to his wishes.

Having thus determined that there was no impracticability in fixing a stone building, it became of the greatest importance to secure a more safe and certain landing on the rock; as it would frequently happen, while the vessels were lying off the rock, waiting for a favourable time to enter the gut, that tides might change, ground swells come on, winds shift, and storms arise, which would of course make it desirable to return to Plymouth, if possible, though the purpose of the voyage was unperformed. In addition to this, when vessels had got with some facility into the gut, they frequently could not get out again without extreme danger: for as the larger sort had not room to turn in it, they were in reality obliged to go out stern forward; the Sugar-loaf rock being so critically placed, with shallow water on both sides of it, that it prohibits a thorough passage. It was true, indeed, that by the skill and expertness of those seamen who had frequently attended the service of the Edystone, not only row boats, but the attendant vessels, after having delivered their cargoes, had been carried quite through, at the top of an high tide, with a fair wind and smooth water: but this was not an experiment to be commonly repeated. The two voyages which Mr Smeaton had made were in a small sailing vessel of about ten or twelve tons burden, which was built for the service, and called the Edystone Boat. It occurred to him, that while the light house was standing, if the boat had been staved on the rocks while lying in the gut, there was a possibility of the men being saved by getting into the house, as the light-keepers would have been ready to throw out a rope to their assistance: but that if any accident of the kind were to happen now that the house was down, and no protection nor shelter to be had, there was little chance of their escape;—and these considerations being likely to cast a damp on every exertion to land, he determined to go out no more without another sailing boat to attend.

The weather being unfavourable for visiting the rock, all exertions were used to forward the work on shore; and, first, a work-yard was chosen in a field adjacent to Mill Bay, about a mile west from Plymouth. The next object was to procure moor stone, or granite; and with this view the author visited Hingstone Downs, and observed the manner of working the stone, which is curious. He next went to Lanlivery, near Fowey harbour, from which place the stone-work for the late light-house had been furnished.

During this time he had made five voyages to the rock with little success: the event of the last had strongly pointed out, that the much greater tonnage of the stone which must be necessary to be carried out and fixed, in case of a stone building, than was requisite in the compositions of his predecessors, would make the uncertainty and delay which they had described as being attendant on their voyages, in order to fix their work, bear far heavier on the scheme; and would thus

Edystone. occasion the whole time of the performance to be lengthened. It appeared, therefore, that had a vessel been fixed within a quarter of a mile, or some such competent distance from the rocks, and which should be capable of lodging the workmen, all their tools and loose materials, the several pieces of wrought stone only excepted, that then the workmen might, by means of small row boats or yawls, have effected a landing both of themselves and of their materials, and have been at work on the rock during the greatest part of those days which otherwise, as voyagers, they would have lost in fruitless endeavours to get to the place of action. Agreeably to this opinion, it was proposed to build a strong and very well found sloop of about fifty tons, with iron chains for mooring her on the rocky ground near the Edystone. A vessel was in fact afterward moored in this situation: but it was one not built for the service, but originally intended to have been stationed as a temporary floating light during the rebuilding of the light-house.

Mr Smeaton now made a sixth voyage to the rock, on which he employed himself for nineteen hours in taking such dimensions as would enable him to make an accurate model of its surface. He likewise attempted a seventh voyage: but being unable to reach the Edystone, he bore away for Falmouth, in order to examine the moor-stone works at Constantine in that neighbourhood. From the difficulties which occurred here, as well as at other places, he was convinced that a sufficient quantity of moor-stone could not be readily and expeditiously procured, in order to complete the whole building; and that he must therefore confine the moor-stone to the outside, as being more durable, and content himself with the use of Portland, or some other free-working stone, for the inside work. In consequence, after making three more voyages to the rock, and completing all the observations which he was desirous of taking there, he visited the isle of Portland in his return to London, and made the necessary agreements for carrying on his work.

On his arrival in London, Mr Smeaton again met the proprietors, from whom he experienced the greatest liberality and confidence: they declared, that as he was now apprized of what was to be done, they left both the time and the means of its accomplishment to him.

‘On this occasion (he observes), I found myself totally unfettered; and perhaps no resolution of the proprietors ever more conduced to the ultimate success of the work than this, which set me so much at liberty. Had they been of the same temper and disposition of by far the greatest part of those who have employed me, both before and since, their language would have been, Get on, Get on, for God’s sake get on! the public is in expectation; get us something speedily to shew, by which we may gain credit with the public!—This, however, was not their tone, which I looked upon as a happy earnest from the proprietors in the outset.’

During his stay in London, he resolved, as an absolutely necessary preliminary step, to form models of the rock, both in its present state and as cut to the intended shape for receiving the building. Connected with the last was a model of the building itself, shewing distinctly how the work was to be adapted to each separate step in the ascent of the rock, and particularly exhibiting the construction of the first entire course after rising to the level of the upper surface of the rock: to

this a solid being fitted, the model shewed the external *Edystone.* form of the whole building, including the lantern; while, by a section on paper, the whole inside work was represented. These models, as well, indeed, as most of the material parts of the business, were the entire work of Mr Smeaton’s own hands. After exhibiting these to the Lords of the Admiralty, who expressed their warmest approbation, he returned to Plymouth on the 23d of July 1756.

On his arrival at Plymouth, he found that Mr Jessop had completely fitted up, for present service, the sloop, which had before been used as an attendant; as well as the Edystone boat, and a large yawl, with sails and oars. Another seaman was now taken into the service, which made the number of the crew six. The Neptune Buss, which had been built for the purpose of exhibiting a temporary light, but which was afterward moored near to the rock, was arrived: but as her destination was not known, all orders for mooring-chains were suspended, and Mr Smeaton was obliged to content himself with preparing cables in the best manner that he could for mooring the sloop in that situation. As the weather was unfavourable, he had but one opportunity of visiting the rock; he therefore applied vigorously to prepare every thing on shore. The first business was to establish the working companies, which were to consist of two complete sets of hands, to relieve each other by turns; so that, whenever winds and tides would permit, the work might be pursued by day and night. In his distribution and management of these people he appears to have acted with great judgment. He made choice of, and agreed with, Mr Thomas Richardson, a master mason of Plymouth, to act as foreman of one of the companies; and also with William Hill, who had been some time foreman to another master mason of the same place, to act as the other foreman. He likewise entered three masons, and nine tanners (Cornish miners), as a company, to go out with Mr Richardson to take the first turn, or week, commencing from Saturday the 31st of July. Mr Jessop was appointed general assistant. The wages of the foremen, while at sea, were to be 5 s. per day certain; and for every hour spent on the rock, the farther premium of 1 s.—but when employed in the work-yard or otherwise on shore, their wages were to be 3 s. 6 d. per day. The wages of the masons were to be 2 s. 6 d. per day certain at sea, with a premium of 9 d. per hour; and the tanners were to have 2 s. per day certain at sea, and 8 d. per hour. In the work-yard, or at shore, the masons were to have 20 d. and the tanners 18 d. per day, and to be paid for over-time when required to work;—and that the seamen might not want inducement to do their utmost in landing the workmen at the Edystone as early as possible at every opportunity, and in supplying them with what was necessary for keeping them at work, over and above their weekly wages, which were settled at 8 s. per week, they were all to receive a premium for every landing on the rock; the master seamen having 2 s. 6 d. and the ordinary men 2 s. to make their advantage equivalent to that of the other workmen, in whatever service the seamen, who were constantly on duty, were employed. Mr Jessop, as general assistant, was to have 10 s. 6 d. per day at sea, and 5 s. per day on land; and every one was to supply himself with victuals.—Mr Smeaton likewise agreed for half an acre of ground on the west side of Mill-bay for

Edystone. a work-yard, as before mentioned, which he marked out, and ordered to be fenced with boards. At this time arrived Mr John Harrison, who was to act as clerk to the Edystone works, with whom a plan was digested for keeping the accounts and correspondence; and for the distinct noting of so great a variety of articles, it was found expedient to open fourteen different books.

Matters being thus settled on shore, and the weather having become more promising, Mr Richardson and his company embarked in the sloop, with her ground tackle on board, attended by the author and Mr Jessop, and having the yawl also properly manned. Having landed on the rock, Mr Smeaton proceeded to fix the centre, and to lay down the lines of the intended work on its surface; and being followed by Mr Richardson, he, with sharp picks, left indelible traces of those lines, so as that the workmen might proceed on them when ever they should be able to land. The roughness of the sea, however, soon rendered it advisable to return to the sloop; and from the same cause it was thought unsafe to attempt to moor her that evening. On the next day, the wind continued to blow very fresh; but on the following they were able to moor the sloop; and every one being anxious to make a beginning, the whole company landed on the rock, and immediately began the work, which was pursued for about four hours, when they were driven off by the sea. On the following day, all hands landed before sun-rise, and worked, during that tide, for six hours; and in the afternoon's tide they again landed, and continued the work, by the help of links, till ten o'clock at night. They pursued this course for some time with very little interruption, working, at an average, for about five hours in each tide.

The weather had now been fair from August 27th to the 14th of September; and in this space they had worked for 177 hours on the rock. During this interval, also, Mr Jessop had prevented a west Indian homeward bound, and a man of war's tender, from driving on the rocks, to which they were approaching, though they themselves were not aware of it. On the 16th, the work on the rock was in the following situation: The lowest new step (the most difficult to work, because the lowest), with its dovetails, was quite completed.—The second step was rough bedded, and all its dovetails scapelled out.—The third step (being the lowest in Mr Rudyerd's work) was smooth bedded, and all the dovetails roughed out.—The fourth was in the like state.—The fifth was rough bedded, and its dovetails were scapelled out; and the sixth was smooth bedded, and all the dovetails roughed out.—Lastly, the top of the rock, the greatest part of the bulk whereof had been previously taken down as low as it could be done with propriety, was now to be reduced to a level with the upper surface of the sixth step; the top of that step being necessarily to form a part of the bed for the seventh or first regular course: so that what now remained, was to bring the top of the rock to a regular floor by picks; and from what now appeared (as all the upper parts that had been damaged by the fire were cut off) the new building was likely to rest on a basis even more solid than the former lighthouses had done.

The equinoctial winds that were now reigning, afforded little prospect of doing much more work on the rock for this season: for though a more moderate interval of weather might be expected, yet that must be

Edystone. employed in weighing the Buss's moorings. To prevent the necessity of this, however, it was an object of consideration, whether they could not dispense with that operation, and thereby have a little more time for work on the rock. Mr Smeaton's contrivance for this purpose was admirable; but it was rendered vain by the bad sailing of the busses. After overcoming many difficulties, the busses with Mr Smeaton on board was driven at a great rate towards the bay of Biscay, in danger every hour of being swallowed up by the waves or dashed in pieces on the rocks of Scilly. At last, on Friday morning the 26th of November, they reached Plymouth Sound, and relinquished all thoughts of returning to their work on the rock that season.

The winter therefore of 1756, and the following spring, were employed in preparing materials for the outwork: the masonry particularly required great attention. It was a desirable object to use large and heavy pieces of stone in the building; yet their size must necessarily be limited by the practicability of landing them with safety. Now small vessels only could deliver their cargoes alongside of this hazardous rock; and these could not deliver very large stones, because the sudden rising and falling of the vessels in the gut amounted frequently to the difference of three or four feet, even in moderate weather; so that in case after a stone was raised from the floor of the vessel, her gunwale should take a swing, so as to hitch under the stone, one of a very large magnitude must, on the vessel's rising, infallibly sink her. From this consideration, it was determined that such stones should be used as did not much exceed a ton weight; though occasionally particular pieces might amount to two tons. That they might attain a certainty in putting the work together on the rock, the stones of each course were tried together in their real situation with respect to each other; and they were so exactly marked, that every stone, after the course was taken asunder, could be replaced in the identical position in which it lay on the platform, within the fortieth part of an inch:—nor was this judged sufficient; for every course was not only tried singly together on the platform and marked, but the course above it was put on it, and marked in the same way; so that every two contiguous courses might fit each other on the outside, and prevent an irregularity in the outline. This degree of accuracy might seem superfluous: but as the nature of the building required the workmen to be in a condition to resist a storm at every step, it became necessary to fix the centre stone first, as being least exposed to the stroke of the sea; and in order to have sure means of attaching all the rest to this, and to one another, it was indispensable that the whole of the two courses should be tried together; in order that, if any defect appeared at the outside, by an accumulation of errors from the centre, it might be rectified on the platform.

Another circumstance, to which Mr Smeaton was particularly attentive, and concerning which his remarks are very valuable, was to ascertain the most proper composition for water cements. In making mortar for buildings exposed to water, *tarras* had been most esteemed: but still there were objections to its use. Mr Smeaton was therefore induced to try the *terra puzzolana*, found in Italy, as a substitute for *tarras*. Fortunately there was a quantity of it in the hands of a merchant at Plymouth, which had been imported as a ve-

Edystone. ture from Civita Vecchia, when Westminster-bridge was building; and which he expected to have sold for that work to a good advantage, but failed in his speculation: for having found that *tarras* answered their purpose, neither commissioners, engineers, nor contractors, would trouble themselves to make a trial of the other material. This was found in every respect equal to *tarras*, as far as concerned the hardening of water-mortar, if not preferable to it; and if made into a mortar with lime produced from a stone found at Aberthaw, on the coast of Glamorganshire, it exceeded, in hardness, any of the compositions commonly used in dry work; and in wet and dry, or wholly wet, was far superior to any which Mr Smeaton had seen, inasmuch that he did not doubt its making a cement that would equal the best merchantable Portland stone in solidity and durability.

These preliminary arrangements being settled, they proceeded, on the 3d of June 1757, to carry out the Neptune bus, and to begin the work. After getting up the moorings (a work of no small difficulty and some danger), and after fixing the fender-piles, the shears, windlafs, &c. the first stone was landed, got to its place, and fixed, on Sunday the 12th of June; and on the next day the first course was completed. On the 14th, the second course was begun: but, in consequence of a fresh gale, the workmen were obliged to quit the rock, after securing every thing as well as possible. Such was the violence of the gale, that it was impracticable for the boats to get out of the gut, otherwise than by passing the Sugar-loaf rock, in which they providentially succeeded. On the 18th, they were again as suddenly driven from their work, and several pieces of stone were washed away by the violence of the sea. In the night of the 6th of July, the watch on the deck of the bus espied a sail on the rocks, and one of the yawls was sent to her relief, which brought back the whole crew, several of whom were in their shirts, and in great distress. It was a snow of about 130 tons burthen, which was returning in ballast from Dartmouth; but not knowing exactly where they were, they had mistaken the rocks for so many fishing-boats, till it was too late to clear them; and on the vessel's striking, she filled so quickly, that the boat floated on deck before they could get into it.

During this time the building went on, though its progress was retarded by various interruptions and accidents; till, at the latter end of August, when the seventh course was nearly finished, a violent storm arose, which carried away the shears and triangles, together with two of the largest stones which had been left chained on the rock! yet notwithstanding these and various other difficulties, the ninth course was completed by the end of September.

"Being now arrived at the eve of October (says Mr Smeaton), I maturely considered our situation; and finding that we had been 18 days in completing the last course, whereas the former one was begun and finished in five, though the weather, both on shore and above head, had remained to all appearance much the same; I from thence concluded it to be very probable, we might not get another course completed in the compass of the month of October: So that when I reflected on the many disasters that we had suffered last year by continuing out to the month of November, and how little work we in reality did after this time, it appear-

ed to me very problematical whether we might be able, with every possible exertion, to get another course finished this season; and considering how very ineligible it was to have a course lie open during the winter in this stage of the work, and that we had now got three complete courses established above the top of the rock, the sum of whose height was four feet six inches; and that we could not leave the work in a more defensible state, whether as relative to the natural violence of the sea, or the possibility of external injuries—from these considerations, it appeared to me highly proper to put a period to the outwork of the present season."

At the commencement of the following year, 1758, the weather proved very tempestuous till March; and on visiting the rock, they discovered that the great buoy on the moorings had been carried away; nor were the mooring chains, though fought with the greatest perseverance, recovered till the middle of May. In consequence of this delay, and from other accidents, the tenth course of the building was not completed till the 5th of July. From this time, the progress was without any very material interruption; so that on the 26th of September the 25th course, being the first of the superstructure, was finished. The work was now so far advanced, that Mr Smeaton made a proposal to the Trinity Board and to the proprietors, of exhibiting a light during the ensuing winter; and for this purpose he continued his operations longer than he otherwise would have done, in order to complete the first room, and make it habitable; but foul weather coming on, he was obliged to quit the rock, and returned to Plymouth. A storm ensued; and, on the next morning, looking out with his telescope, he could discern the house with the sea breaking over it, but nothing of the bus. On the following day, the air being more clear, he had a distinct view of the building; but the bus was really gone. This was a day of double regret, as it likewise brought a negative on his proposal for exhibiting a light from the house during the winter. The bus had run into Dartmouth harbour; she was brought home; and the work on the rock being secured against the winter, the operations of the third season were closed.

During the early part of 1759, Mr Smeaton was employed in London in forming and making out the necessary designs for the iron rails of the balcony, the cast iron, the wrought iron, and the copper works for the lantern, together with the plate glass work. It was not till the 22d of June that he arrived at Plymouth. As the moorings had been again lost, new chains were provided, and the bus was once more fixed in her situation. On the 5th of July he landed on the rock, and found every thing perfectly sound and firm, without the least perceptible alteration, excepting that the cement, used in the first year, now in appearance approached the hardness of the moorstone; and that used in the last year had the full hardness of Portland; but on hauling up the stones for the next circle from the store-room, where they had been deposited, he had the mortification to find only seven instead of eight. It was imagined that a body of falling water, making its way through the open ribs of the centre, had washed this stone out of the store-room door, though it weighed between four and five hundred weight.

The progress of the work, however, was now such, that

Edystone. that a whole room, with its vaulted cover, was built complete in seven days.

On the 17th of August the main column was completed.

On the 27th Mr Richardson and his company left the Edystone, and gave an account that they had lived in it since the 23d, having found it much more warm than the bus's hold and cabin.

They had now finished every thing belonging to the masonry. The work of the cupola was going on briskly in the yard at Mill-bay, though it was retarded by the successive illnesses of the two principal copper-smiths. However, by the exertions of Mr Smeaton, who was himself ready to work at every business, all matters were put in such forwardness, that by the 8th of September there was nothing to prevent the frame of the lantern from being fixed in its place but bad weather. It was not till the 15th that the weather permitted the boats to deliver their cargoes. The 16th was remarkably fine; so that by the evening the whole frame of the lantern was screwed together, and fixed in its place. On the 17th, which was also exceedingly fine, the cupola was brought out, and the shears and tackle were set up for hoisting it.

“ This (says Mr Smeaton) perhaps may be accounted one of the most difficult and hazardous operations of the whole undertaking; not so much on account of its weight, being only about 11 cwt. as on account of the great height to which it was to be hoisted clear of the building, and so as, if possible, to avoid such blows as might bruise it. It was also required to be hoisted a considerable height above the balcony floor; which, though the largest base that we had for the shears to stand on, was yet but 14 feet within the rails, and therefore narrow in proportion to their height. About noon the whole of our tackle was in readiness; and in the afternoon the Weston (boat) was brought into the gut, and in less than half an hour her troublesome cargo was placed on the top of the lantern without the least damage. During the whole of this operation it pleased God that not a breath of wind discomposed the surface of the water, and there was the least swell about the rocks I had observed during the season.

“ Tuesday, September 18th, in the morning, I had the satisfaction to perceive the Edystone boat, on board of which I expected the ball to be; and which being double gilt, I had ordered the carriage of it to be carefully attended to. The wind and tide were both unfavourable to the vessel's getting soon near us; therefore, being desirous to get the ball screwed on before the shears and tackle were taken down, one of the yawls was dispatched to bring it away. This being done, and the ball fixed, the shears and tackle were taken down, which took up nearly as much time as was employed in setting them up; that is, near 12 hours each, in the whole, to do the work of an hour.— I must observe, that by choice I screwed on the ball with mine own hands, that in case any of the screws had not held quite tight and firm, the circumstance might not have been slipped over without my knowledge; being well aware, that even this part would at times come to a considerable stress of wind and sea, and which could not be replaced without some difficulty in case any thing should fail.— It may not be amiss to intimate to those who may in future have to perform the same operation, that the scaffold on which this was done con-

Edystone. sisted of four boards only, well nailed together, at such distances as to permit it to be lifted over the ball when done with. It rested on the cupola, encompassing its neck; and Roger Cornthwaite, one of the masons, placed himself on the opposite side upon it, to balance me while I moved round to fix the screws.”

Respecting the disposition of the internal part of the edifice, Mr Smeaton fixed the beds in the uppermost room, and the fire-place, which constituted the kitchen, in the room below it; whereas, in the late house, the upper room was the kitchen, and the beds were placed in one of the rooms below: the consequence of which was, that the beds and bedding were generally in a very damp and disagreeable state. The present disposition has perfectly answered the end proposed, as nothing can be more completely dry than the two habitable rooms.

On the 1st of October, every thing being finished, and the chandeliers hung, there was nothing to hinder a trial by lighting the candles in the day-time. Accordingly 24 candles were put into their proper places, and were continued burning for three hours, during which time it blew a hard gale; and a fire being kept at the same time in the kitchen, they both operated without any interference; not any degree of smoke appearing in the lantern nor in any of the rooms: and by opening the vent-holes, which had been made in the bottom of the lantern for occasional use, it could be kept quite cool; whereas, in the late light-house, it used to be so hot, especially in the summer, as to give much trouble by the running of the candles.

All being thus in readiness, and a conductor, in case of lightning, being adapted to the building, notice was given to the Trinity-house that the light would be exhibited on the 16th of October 1759. The season of the year being now advanced to that which was always very precarious, the Neptune bus was unmoored, and on the 9th of October she came to an anchor in Plymouth harbour.— “ And thus (says Mr Smeaton), after innumerable difficulties and dangers, was a happy period put to this undertaking, without the loss of life or limb to any one concerned in it, or accident, by which the work could be said to be materially retarded.”

With regard to subsequent occurrences, it is truly observed, that the best account is, that after a trial of 40 years, which have elapsed since the finishing of the building, it still remains in its original good condition. A few particulars are however interesting. On the 19th of October Mr Smeaton, with Mr Jessop, &c. visited the house, and, landing, found all well. Henry Edwards, one of the light-keepers, gave an account that they lighted the house as they were directed, and found the lights to burn steadily, notwithstanding it blew very hard; that they had the greatest seas on the days immediately preceding the lighting; and that then the waves broke up so high, that had they not been thrown off by the cove course, they would have endangered breaking the glass in the lantern; that when the seas broke the highest, they had experienced a sensible motion; but that, as it was barely perceptible, it had occasioned them neither fear nor surprize.

During his stay at Plymouth, in the times of stormy weather, Mr Smeaton took several opportunities of viewing the light-house with his telescope from the Hoe, and also from the garrison; both which places were sufficiently elevated to see the base of the building, and the whole of the rock at low water in clear weather;

Edyſtone.

ther; and though he had many occaſions of viewing the unfiniſhed building when buried in the waves in a ſtorm at ſouth-weſt, yet having never before had a view of it under this circumſtance in its finiſhed ſtate, he was aſtoniſhed to find that the account given by Mr Winſtanley did not appear to be at all exaggerated. At intervals of a minute, and ſometimes of two or three, when a combination happened to produce one overgrown wave, it would ſtrike the rock and the building conjointly, and fly up in a white column, enwrapping it like a ſheet, riſing at leaſt to double the height of the houſe, and totally intercepting it from the ſight; and this appearance being momentary, both as to its riſing and falling, he was enabled to judge of the comparative height very nearly by the comparative ſpaces, alternately occupied by the houſe and by the column of water in the field of the teleſcope.

The year 1759 concluded with ſome very ſtormy weather; and in January 1760, Mr Jeſſop viſited the houſe, but could not land. He got a letter, however, from Henry Edwards, acquainting him that there had been ſuch very bad weather that the ſea frequently ran over the houſe; ſo that for 12 days together they could not open the door of the lantern nor any other. He ſaid, “the houſe did ſhake as if a man had been up in a great tree. The old men were almoſt frightened out of their lives, wiſhing they had never ſeen the place, and curſing thoſe that firſt perſuaded them to go there. The fear ſeized them in the back; but rubbing them with oil of turpentine gave them relief.” He farther mentioned, that on the 5th of December, at night, they had a very great ſtorm; ſo that the ladder, which was laſhed below the entry door, broke looſe, and was waſhed away. Alſo, on the 13th, there was ſo violent a ſtorm of wind that he thought the houſe would overſet; and at midnight the ſea broke one pane of glaſs in the lantern. They had a very melancholy time of it, having alſo had a great deal of thunder and lightning.—“The ſtorms (obſerves Mr Smeaton) which the building has now ſuſtained without material damage, convince us, and every one, of the ſtability of the ſtone light-houſe, except thoſe (who are not a few) who had taken a no-

tion that nothing but wood could reſiſt the ſea upon the Edyſtone rocks; who ſaid, that though they allowed it was built very ſtrong, yet if ſuch a ſtorm as had deſtroyed Winſtanley’s light-houſe was again to happen, they doubted not but it muſt ſhare the ſame fate. The year 1762 was uſhered in with ſtormy weather, and indeed produced a tempeſt of the firſt magnitude; the rage of which was ſo great, that one of thoſe who had been uſed to predict its downfall was heard to ſay, If the Edyſtone light-houſe is ſtanding now, it will ſtand till the day of judgment. And, in reality, from this time, its exiſtence has been ſo entirely laid out of mens minds, that whatever ſtorms have happened ſince, no inquiry has ever been made concerning it.”

For the length of this detail we cannot bring ourſelves to make any apology. If there be a few of our readers to whom it may appear tedious, we are perſuaded that there are many more to whom it will be in a high degree intereſting; while ſuch of them as are engineers will derive inſtruction even from this very abridged hiſtory of the Edyſtone light-houſe.

EFFECTION, denotes the geometrical conſtruction of a propoſition. The term is alſo uſed in reference to problems and practices, which, when they are deducible from, or founded upon, ſome general propoſitions, are called the *geometrical effection* of them.

ELASTICITY. In addition to the article in the *Encyclopædia*, ſee, in this *Supplement*, the view of Boscovich’s theory of natural philoſophy, n^o 26.

ELECTIONS, or **CHOICE**, ſignify the ſeveral different ways of taking any number of things propoſed, either ſeparately, or as combined in pairs, in threes, in fours, &c.; not as to the order, but only as to the number and variety of them. Thus, of the things *a, b, c, d, e*, &c. the elections of one thing are (*a*), $1 = 2^1 - 1$, two things are (*a, b, ab*), $3 = 2^2 - 1$, three things are (*a, b, c, ab, ac, bc, abc*), $7 = 2^3 - 1$, &c.; and of any number *n*, all the elections are $2^n - 1$; that is, one leſs than the power of 2 whoſe exponent is *n*, the number of ſingle things to be choſen, either ſeparately or in combination.

ELECTRICITY.

WE cannot but be ſomewhat ſurpriſed that, among the many attempts which have been made by the philoſophers of Britain to explain the wonderful phenomena which are claſſed under this name, no author of eminence, beſides the Hon. Mr Cavendiſh and Lord Mahon, have availed themſelves of their ſuſceptibility of mathematical diſcuſſion; and our wonder is the greater, becauſe it was by a mathematical view of the ſubject, in the phenomena of attraction and repulſion, that the celebrated philoſopher Franklin was led to the only knowledge of electricity that deſerves the name of ſcience; for we had ſcarcely any leading facts, by which we could claſs the phenomena, till he publiſhed his theory of *poſitive* and *negative*, or *plus* and *minus*, electricity. This is founded entirely on the phenomena of attraction and repulſion. Theſe furniſh us with all the indications of the preſence of the mighty agent, and the marks of its kind, and the meaſures of its force. Mechanical force accompanies every other appearance; and this ac-

companionment is regulated in a determinate manner. Many of the effects of electricity are ſtrictly mechanical, producing local motion in the ſame manner as magnetiſm or gravitation produce it. One ſhould have expected that the countrymen of Newton, prompted by his ſucceſs and his fame, would take to this mode of examination, and would have endeavoured to deduce, from the laws obſerved in the action of this motive force, an explanation of other wonderful phenomena, which are inſeparably connected with thoſe of attraction and repulſion.

But this has not been the caſe, if we except the labours of the two philoſophers above mentioned, and a few very obvious poſitions, which muſt occur to all the inventors and improvers of electrometers, batteries, and other things of meaſurable nature.

This view has, however, been taken of the ſubject by a philoſopher of unqueſtioned merit, Mr Æpinus of the Imperial Academy of St Petersburg. This gentleman,

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Elections.

gentleman, struck with the resemblance of the electrical properties of the tourmalin to the properties of a magnet, which have always been considered as the subject of mathematical discussion, fortunately remarked a wonderful similarity in the whole series of electrical and magnetical attractions and repulsions, and set himself seriously to the classification of them. Having done this with great success, and having maturely reflected on Dr Franklin's happy thought of plus and minus electricity, and his consequent theory of the Leyden phial, he at last hit on a mode of conceiving the whole subject of magnetism and electricity, that bids fair for leading us to a full explanation of all the phenomena; in as far, at least, as it enables us to class them with precision, and to predict what will be the result of any proposed treatment. He candidly gives it the modest name of a hypothesis.

This was published at St Petersburg in 1759, under the title of *Theoria Electricitatis et Magnetismi*, and is unquestionably one of the most ingenious and brilliant performances of the eighteenth century. It is indeed most surprising that it is so little known in this country. This, we imagine, has been chiefly owing to the very slight and almost unintelligible account which Dr Priestley has given of it in his history of electricity; a work which professes to comprehend every thing that has been done by the philosophers of Europe and America for the advancement of this part of natural science, and which indeed contains a great deal of instructive information, and, at the same time, so many loose conjectures and insignificant observations, that the reader (especially if acquainted with the Doctor's character as an unwearied bookmaker) reasonably believes that he has let nothing slip that was worthy of notice. We do not pretend to account for the manner in which Dr Priestley has mentioned this work, so much, and so deservedly celebrated on the continent. We cannot think that he has read it so as to comprehend it; and imagine, that seeing so much algebraic notation in every page, and being at that time a novice in mathematical learning, he contented himself with a few scattered paragraphs which were free of those embarrassments; and thus could only get a very imperfect notion of the system. The Hon. Mr Cavendish has done it more justice in the 61st volume of the Philosophical Transactions, and considers his own most excellent dissertation only as an extension and more accurate application of Æpinus's theory. That we have not an account of this exposition of the Franklinian theory of electricity in our language, is a material want in British literature; and we trust, therefore, that our readers will be highly pleased with having the ingenious discoveries of the great American philosopher put into a form so nearly approaching to a system of demonstrative science.

We propose, therefore, in this place, to give such a brief account of Æpinus's theory of electricity, as will enable the reader to reduce to a very simple and easily remembered law all the phenomena of electricity which have any close dependence on the mechanical effects of this powerful agent of Nature; referring for a demonstration of what is purely mathematical to Sir Isaac Newton's Principia, and the Dissertation by Mr Cavendish already mentioned, except in such important articles as we think ourselves able to present in a new, and, we hope, a more familiar form. We do not mean,

in this place, to give a system of philosophical electricity, nor even to narrate and explain the more remarkable phenomena. Of these we have already given a vast collection in the article ELECTRICITY, *Encycl.* We confine ourselves to the phenomena which may be called *mechanical*, producing measurable motion as their *immediate* effect; and thus giving us a principle for the mathematical examination of the cause of electrical phenomena. We shall consider the reader as acquainted with the other physical effects of electricity, and shall frequently refer to them for proofs.

Moreover, as our intention is merely to give a synoptical view of this elaborate and copious performance of Mr Æpinus, hoping that it will excite our countrymen to a careful perusal of so valuable a work, we shall omit most of the algebraic investigations contained in it, and present the conclusions in a more familiar, and not less convincing form. At the same time we will insert the valuable additions made by Mr Cavendish, and many important particulars not noticed by either of those gentlemen.

HYPOTHESIS OF ÆPINUS.

THE phenomena of electricity are produced by a fluid ^{Hypothesis.} of peculiar nature, and therefore called the ELECTRIC FLUID, having the following properties:

1. Its particles repel each other, with a force decreasing as the distances increase. 2.

2. Its particles attract the particles of some ingredient in all other bodies, with a force decreasing, according to the same law, with an increase of distance; and this attraction is mutual. 3.

3. The electric fluid is dispersed in the pores of other bodies; and moves, with various degrees of facility, through the pores of different kinds of matter. In those bodies which we call *non-electrics*, such as water or metals, it moves without any perceivable obstruction; but in glass, resins, and all bodies called *electrics*, it moves with very great difficulty, or is altogether immoveable. 4.

4. The phenomena of electricity are of two kinds; 5.
1. Such as arise from the actual motion of the fluid from a body containing more into one containing less of it. 2. Such as do not immediately arise from this transference, but are instances of its attraction and repulsion.

These things being supposed, certain consequences necessarily result from them, which ought to be analogous to the observed phenomena of electricity, if this hypothesis be complete, or some farther modification of the assumed properties is necessary, in order to make the analogy perfect.

Suppose the body A (fig. 1.) to contain a certain quantity of fluid. Its particles adjoining to the surface, such as P, are attracted by the particles of common matter in the body, but repelled by the other particles of the fluid. The totality of the attractive forces acting on P may be equal to the totality of the repulsive forces, or may be unequal. If these two sums are equal, P is in equilibrio, and has no tendency to change its place. But there may be such a quantity of fluid in the body, that the repulsions of the fluid exceed the attractions of the common matter. In this case, P has a tendency to quit the body, or there is an expulsive force acting on it, and it *will* quit the body if it be moveable. 6.
XXIV.

moveable. Because the same must be admitted in respect of every other particle of moveable fluid, it is plain that there will be an efflux, till the attraction of the common matter for the particles of fluid is equal to the repulsion of the remaining fluid. On the other hand, if the primitive repulsion of the fluid acting on the particle P be less than the attractions of the common matter, there will be the same, or at least a similar, superiority of attraction acting on the fluid residing in the circumambient bodies; and there will be an influx from all hands, till an equilibrium be restored.

7
Natural
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why so call-
ed.

Hence it follows, that there may always be assigned to any body such a quantity of fluid that there shall be no tendency either to efflux or influx. But if the quantity be increased, and nothing prevent the motion, the redundant fluid will flow out; and if the proper quantity be diminished, there will be an influx of the surrounding fluid, if not prevented by some external force. This may be called the body's NATURAL QUANTITY; because the body, when left to itself, will always be reduced to this state.

8. If two bodies A and B, contain each its natural quantity, they will not exert any sensible action on each other; for, because the fluid contained in B is united by attraction to the common matter, and is also repelled by the fluid in A, it necessarily follows that the whole body B is repelled by the fluid in A. But, on the other hand, the matter in A attracts the fluid in B, and consequently attracts the whole body B: Similar action is exerted by B on A. These contrary forces are either equal, and destroy each other, or unequal, and one of them prevails. This equality or inequality evidently depends on the quantity of fluid contained in one or both of the bodies (n^o 7.) Now it is known that bodies left entirely to themselves neither attract nor repel; and it follows from the hypothetical properties of the fluid, that if there be either a redundancy or deficiency of fluid, there will be an efflux or influx, till the attractions and repulsions balance each other. Therefore the internal state of two bodies which neither attract nor repel each other, is that where each contains its natural quantity of electric fluid.

9. In order, therefore, to conceive distinctly the state of a body containing its natural quantity, and to have a distinct notion of this natural quantity, we must suppose that the quantity of fluid competent to a particle of matter in A repels the fluid competent to a particle of matter in B, just as much as it attracts that particle of matter; and also, that the fluid belonging to a particle of matter in A, repels the fluid belonging to a particle of matter in B, just as much as the particle of matter in A attracts it. Thus the whole fluid in the one repels the whole fluid in the other as much as it attracts the whole matter.

Since this must be conceived of every particle of common matter in a body, we must admit, that when a body is in its natural state, the quantity of electric fluid in it is proportional to the quantity of matter, every particle being united with an equal quantity of fluid. This, however, does not necessarily require that different kinds of matter, in their natural or saturated state, shall contain the same proportion of fluid. It is sufficient that each contains such a quantity, uniformly distributed among its particles, that its repulsion for the fluid in another body is equal to its attraction for the com-

mon matter in it. It is, however, more probable, for reasons to be given afterwards, that the quantity of electric fluid attached, or competent, to a particle of all kinds of matter is the same.

We shall now consider more particularly the immediate results of this hypothesis, in the most simple cases, from which we may derive some elementary propositions.

Since our hypothesis is accommodated to the fact, that bodies in their natural state, having their natural quantity of electric fluid, are altogether inactive on each other, by making this natural quantity such, that its mutual repulsion exactly balances its attraction for the common matter—it follows, that we must deduce all the electric phenomena from a redundancy or deficiency of electric fluid. This accordingly is the Franklinian doctrine. The redundant state of a body is called by Dr Franklin POSITIVE OR PLUS ELECTRICITY, and the deficient state is called NEGATIVE OR MINUS ELECTRICITY.

A body may contain more than its natural quantity, or less, in every part, or it may be redundant in one place and deficient in another. These different conditions will exhibit different appearances, which must be considered first of all.

Let the body (fig. 1.) be supposed in its natural state throughout, which we shall generally express by saying that it is SATURATED; and let us express the quantity of fluid required for its saturation by the symbol Q. Let P be a superficial particle of the fluid, which we shall in future call simply the matter, and it is repelled equally by the fluid. Let us call the attraction a, and the repulsion r. Then the force with which the superficial particle is attracted by the body, must be $= a - r$, and $a - r$ must be $= 0$, because $a = r$. Let the quantity f of fluid be added to the body, and uniformly distributed through its substance. Then, because we must admit that the action is in proportion to the quantity of acting fluid, and this is now $Q + f$, we have $Q : Q + f = r : \frac{Q + f}{Q} \times r$; and therefore

P is repelled by the whole fluid with the force $\frac{Q + f}{Q} \times r$,

or $\frac{Qr}{Q} + \frac{fr}{Q}$, or $r + \frac{fr}{Q}$. But it is attracted by the common matter in the same manner as before, that is, with a force $= a$. Therefore the whole action on P is $= a - r - \frac{fr}{Q}$. But $a - r = 0$. Therefore the whole action on P is $= -\frac{fr}{Q}$; that is, P is repelled with the force $\frac{fr}{Q}$.

This will perhaps be as distinctly conceived by recollecting, that as much of the fluid as was necessary for saturation, that is, the quantity Q, puts the particle P in equilibrio; and therefore we need only consider the action of the redundant fluid f. To find the repulsive force of this, say $Q : f = r : \frac{fr}{Q}$, and prefix the sign —; because we are to consider attractions as positive, and repulsions as negative, quantities.

Unless, therefore, the particle P be withheld by some other

ther force, it will quit the body, being expelled by a force

$\frac{fr}{Q}$. And as every superficial particle is in a similar situation, we see that there will be an efflux from an overcharged body, till all the redundant fluid has quitted it. This efflux will indeed gradually diminish as

the expelling force $\frac{fr}{Q}$ diminishes; that is, as f diminishes, but will never cease till f be reduced to nothing. But if there be either an external force acting on the superficial fluid in the opposite direction, or some internal obstruction to its motion, the efflux will stop when the remaining expelling force is just in equilibrio with this external force, or this obstruction.

On the other hand, if the body contains less than its natural quantity of fluid, there will be an influx from without; for if there be a deficiency of fluid $= f$, the particle P will be repelled with the force $\frac{Q - f \times r}{Q}$

$= r - \frac{fr}{Q}$. It is attracted with the force a ; and there-

fore the whole action is $= a - r + \frac{fr}{Q} = + \frac{fr}{Q}$ (because $a - r = 0$); that is, P is attracted with the force $\frac{fr}{Q}$. Fluid will therefore enter from all quarters, as long as there is any deficiency of the quantity necessary for saturation, unless it be opposed by some external force, or hindered by some internal obstruction.

When there is a deficiency of fluid, there is a redundancy of matter, such that its attraction for external fluid is equal to the repulsion of a quantity f of fluid. This confirms the assumption in n^o 10, that the action of a body on the electric fluid depends entirely on the redundant fluid, or the redundant matter of the body.

The efflux or influx may be prevented, either by surrounding the body with substances, through the pores of which the fluid cannot move at all, or by the body itself being of this constitution. And thus we see, that the very circumstance of being impervious to the fluid, or completely permeable, renders the body capable or incapable of permanently exhibiting electrical phenomena, if surrounded by permeable bodies. This circumstance alone, therefore, is sufficient to constitute the difference between *electrics per se*, and *non-electrics*.— Here, then, is a numerous class of phenomena, which receive an explanation by this hypothetical constitution of the electric fluid. All *electrics per se* are bodies fit for confining electricity in bodies which are rendered capable (by whatever means) of producing electrical phenomena; and no conductor, or substance which allows the electricity to pass through it, can be made electric by any of the means which produce that effect in *insulators*. And it is well known that the electricity of *electrics* is vastly more durable than that of *non-electrics* in similar situations. It is true, indeed, that an electric, which has been excited so as to exhibit electric phenomena with great vivacity, loses this power very quickly if plunged into water, or any other conducting body. But this is owing to the redundancy or deficiency being quite superficial, so that the parts which are disposed to give out or to take in the fluid are in immediate contact with the conducting matter. That

the redundancy or deficiency is superficial, follows from this hypothesis; for when the surface is overcharged by the means employed for exciting, the impermeability of the electric *per se* prevents this redundant fluid from penetrating to any depth; and when the surface has been rendered deficient in fluid, the same impermeability prevents the fluid from expanding from the interior parts, so as to contribute to the replenishing the superficial stratum with fluid. If, indeed, we could fall on any way of overcharging the interior parts of a glass ball, or of abstracting the natural quantity from them, it is highly probable, that it would continue to attract or repel even after it had been plunged in water. Although the surrounding water would instantly take off the fluid redundant contained in the very surface, the repulsion of the fluid in the internal parts would still be sensible; nay, if a very small permeability be supposed, the body would again become overcharged at the surface; just as we see, that when we plunge a red-hot ball of iron into water, and take it out again immediately, it is black on the surface, and may be touched with the finger; but in half a minute after, it again becomes red hot. Perhaps this may be accomplished with a globe of sealing wax, which is permeable while liquid, by electrifying it in a particular way while in that state, and allowing it to freeze. But the reader is not far enough advanced in the hypothesis to understand the process which must be followed. He cannot but recollect, however, many examples in coated glass, &c. where the electricity is most pertinaciously retained by a surface in very close contact with conductors.

Let us now suppose a body NS (fig. 2.) containing in the half NA a quantity f of redundant fluid, and in the half AS let there be a deficiency g of fluid; that is, let there be a quantity of matter unfaturated and such as will attract fluid as much as the quantity of fluid would repel it. Let the fluid necessary for the saturation of each half of NS be Q , as before. Let the attraction of the whole matter of NA for a particle of fluid at N be a ; and let r be the repulsion exerted on the same particle N by the whole uniformly distributed fluid in NA, and let r' be the repulsion exerted by the same quantity of fluid in the remote part SA. Then the force with which the particle N or S is attracted by the merely saturated body NS must be $= a - r - r'$. This is evidently nothing, if the body be in its natural state. But as NA contains the redundant fluid f , and SA is deficient by

the quantity g , the whole action must be $a - \frac{Q + f \times r}{Q}$

$- \frac{Q - g \times r'}{Q}$. But because $a - r - r' = 0$, the

action becomes $= \frac{g r' - f r}{Q}$, or because r is greater

than r' , the particle N is repelled with the force $\frac{f r - g r'}{Q}$.

In like manner the particle S is attracted with the force $\frac{g r - f r'}{Q}$.

In the mean time, a particle C, situated at the middle, must be in equilibrio, if the body be in its natural state, being equally attracted, and also equally repelled, on both sides. But as we suppose that NA is overcharged

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ged with the quantity f , C must be repelled in the direction CS with the force $\frac{f r}{Q}$. And if we also suppose that AS is deficient by the quantity g , C is attracted in the direction CS with a force $\frac{g r}{Q}$. Therefore, on the whole, it is urged in the direction CS with the force $\frac{f r + g r}{Q}$, or $\frac{f + g \times r}{Q}$.

17
It will be uniformly diffused, unless obstructed.

Hence we learn, that as long as there is any redundancy in AN, and deficiency in AS, there is a tendency of the redundant fluid to move from N toward S; and, if the body be altogether permeable by the electric fluid, we cannot have a permanent state till the fluid is similarly distributed, and equally divided, between the two halves of NS. Therefore a state like that assumed in this example cannot be permanent in a conducting body, unless an external force act on it; but it may subsist in a non-conductor, and in a lesser degree, in all imperfect conductors.

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Nature of the obstruction.

It is necessary, in this place, to consider a little the nature of that resistance which must be assigned to the motion of the electric fluid through the pores of the body. If it resemble the resistance opposed by a perfect fluid, arising solely from the inertia of its particles; then there is no inequality of force so minute but that it will operate a uniform distribution of the fluid, or at least a distribution which will make the excess of the mutual attractions and repulsions precisely equal and opposite to the external force which keeps it in any state of unequal distribution. But it may resemble the resistance to the descent of a parcel of small shot disseminated among a quantity of grain, or the resistance to motion through the pores of a plastic or ductile body, such as clay or lead. Here, in order that a particle may change its place, it must overcome the tenacity of the adjoining particles of the body. Therefore, when an unequal distribution has been produced by an external force, the removal or alteration of that force will not be followed by an equable distribution of the fluid. In every part there will remain such an inequality of distribution, that the want of equilibrium between the electric attractions or repulsions is balanced by the tenacity of the parts.

19. We learn farther from the foregoing propositions, that a particle at N is less repelled than if the part AS were overcharged as AN is: for in that case, it would be expelled by a force $\frac{f \times r + r'}{Q}$, which is much greater than $\frac{f r - g r'}{Q}$. And, in like manner, the particle S

is attracted with less force than it would be if NA were equally undercharged with SA.

20. The condition of the body now described may be changed by different methods. The redundant fluid in AN may flow into AS, where it is deficient, till the whole be uniformly distributed; or fluid may escape from AN, and fluid may enter into AS, till the body be in its natural state. The first method will be so much the slower as the body is less permeable, or more remarkably *electric per se*; and the second method will be slower than if the whole body were overcharged or undercharged.

21. What we have been now saying of a body NS that

is overcharged at one end, and undercharged at the other, and capable of retaining this state, is applicable, in every particular, to two conducting bodies NA and SA', having a non-conducting body Z interposed between them, as in fig. 3. All the formulas, or expressions of the forces which tend to expel or to draw in fluid, are the same as before. Perhaps this is the best way of forming to ourselves a distinct notion of the body that is redundant in fluid at one end, and deficient at the other. And we perceive, that the state of the two bodies, separated by the electric Z, will be more permanent when one is overcharged, and the other undercharged, than if both are either over or undercharged.

It must be remarked, that the quantities f and g were taken at random. They may be so taken, that the force with which the fluid tends to escape at N, or to enter at S, may be nothing, or may even be changed where it is to their opposite. Thus, in order that there may be no tendency to escape from N, we have only to suppose

22
A body may be inactive, or neutral, where it is redundant or deficient.

$g r' - f r = 0$, or $g : f = r : r'$, and $g = \frac{f r}{r'}$. In this case, the particle at N is as much attracted by the redundant matter in SA as it is repelled by the redundant fluid in NA.

When the extremity N is rendered inactive in this manner, the condition of the other extremity S is considerably changed. To discover this condition, put

23
Conditions for this.

$\frac{f r}{r'}$ in place of g in the formula $\frac{g r - f r'}{Q}$, which expresses the attraction for a particle at S, and we obtain $\frac{f \times r^2 - r'^2}{Q r'}$.

On the other hand, we may have the redundancy and deficiency so balanced, that there shall be no tendency to influx at S. For this purpose, we must make

24.

$g = \frac{f r'}{r}$. When this obtains at S, the action at N will be had by putting $\frac{f r'}{r}$ in place of g in the formula $\frac{f r - g r'}{Q}$, and this will give us $\frac{f \times r'^2 - r^2}{Q r}$ for the force repelling a particle at N.

When the tendency to efflux or influx is induced in this manner, by a due proportion of the redundancy and deficiency of electric fluid, the part of the body where this obtains is by no means in its natural state, and may contain either more or less than its natural quantity. But it neither acts like an overcharged nor like an undercharged body, and may therefore be called NEUTRAL. The reader, who is conversant with electrical experiments, will recollect numberless instances of this, and will also recollect that they are important ones. Such, for example, is the case with the plates and covers of the electrophorus. These circumstances, therefore, claim particular attention.

25.

As the quantities f and g may be so chosen, that the apparatus shall be neutral, either at S or at N; they may likewise be so, that either end shall exhibit either the appearance of redundancy or deficiency. Thus, instead of neutrality at N, we may have repulsion, as at the first, by making g less in any degree than $\frac{f r}{r'}$. If, on the contrary, g be greater than $\frac{f r}{r'}$, the extremity N, tho' overcharged, will attract fluid. In like manner, if g

26.

bc

be less than $\frac{f r'}{r}$, the extremity S, although undercharged, will repel fluid.—We may make the following general remarks.

1. Both extremities N and S cannot be neutral at the same time: for since the neutrality arises from the increased quantity of redundancy or deficiency at the other extremity, so as to compensate for its greater distance, the activity of that extremity must be proportionably greater on the fluid adjoining to its surface, whether externally or internally. When an overcharged extremity is rendered neutral, the other extremity attracts fluid more strongly; and when a deficient extremity is rendered neutral, the other repels fluid more strongly. All these elementary corollaries will be fully verified afterwards, and give clear explanations of the most curious phenomena.

2. We have been supposing that the redundant fluid is uniformly spread, and that the body is divided into equal portions; but this was merely to simplify the procedure and the formulæ. The reader must see that the general conclusions are not affected by this, and that similar formulæ will be obtained, whatever is the disposition of the fluid. We cannot tell in what manner the redundant fluid is disposed, even in a body of the simplest form, till we know what is the variation of its attraction and repulsion by a change of distance; and even when this has been discovered, we find it difficult in most cases, and impossible in many, to ascertain the mode of distribution. We shall learn it in some important cases, by means of various phenomena judiciously selected.

28. A body may be considered in many divisions, in some of which the fluid is redundant, and in others deficient. We may express the repulsion of the whole of this body in the same way as we express that of a body considered in two divisions, using the letters $f, g, h, &c.$ to express the quantities of redundant or deficient fluid in each portion, while Q expresses the quantity necessary for saturating each of them; and the repulsion at different distances may be expressed by $r, r', r'', r''', &c.$ as they are more and more remote; and we may express their action as attractive or repulsive by prefixing the sign $+$ or $-$. Thus the attraction may be $(f r - g r' + h r'' - i r''')$, &c.

29. Having obtained the expressions of the invisible actions of electrified bodies on the fluid within them, or surrounding them, let us now consider their sensible actions on other bodies, producing motion, or tendencies to motion.

Here it is obvious that the mechanical phenomena exhibited are what may be called *remote EFFECTS* of the acting forces. The immediate effects, or the mutual actions of the particles, are not observed, but hypothetically inferred. The tangible matter of the body is put in motion, in consequence of its connection with the fluid residing in the body, which fluid is the only subject of the action of the other body.

In considering these phenomena, we shall content ourselves with a more general view of the actions which take place between the fluid or tangible matter of the one body, and the fluid or matter of the other, so as to gain our purpose by more simple formulæ than those hitherto employed. They were premised, however, be-

cause we *must* have recourse to them on many very important particular occasions.

Let there be two bodies, A and B, in their natural state. Let the tangible matter in A be called M, and let the fluid necessary for its saturation be called F, and let m and f be the tangible matter and the fluid in B. Let the mutual action between a single particle of fluid and the matter necessary for its saturation be expressed by the indeterminate symbol z , because it varies by a change of distance.

The actions are mutual and equal. Therefore when the motion of B by the action of A is determined, the motion of A is also ascertained. We shall therefore only consider how A is affected. 1. Every particle of fluid in A tends toward every particle of matter in B with the force z . The whole tendency of A toward B may therefore be expressed by z , multiplied by the product of F and m . 2. Every particle of fluid in A is repelled by every particle of fluid in B, with the same force z . 3. Every particle of matter in A is attracted by every particle of fluid in B, with the same force. We may express this more purely and briefly thus:

1. F tends toward m with the force $+ F m z$
2. F tends from f with the force $- F f z$
3. M tends toward f with the force $+ M f z$

Therefore the sensible tendency of A to or from B will be $= z \times F m + M f - F f$. But, by the hypothesis, the attraction of a particle of the fluid in A for a particle of the matter in B, is equal to its repulsion for the particle or parcel of the fluid attached or competent to that particle of matter. Therefore the attraction $F m z$ is balanced by the repulsion $F f z$. Therefore there remains the attraction of the matter in A for the fluid in B unbalanced, and the body A will tend toward the body B with the force $M f z$, or B attracts A with the force $M f z$. A must therefore move toward B. And, by the 3d law of motion, B must move toward A with equal force.

But the fact is, that no tendency of any kind is observed between bodies in their natural state. The hypothesis, therefore, is not complete. If we abide by it, as far as it is already expressed, we must farther suppose, that there is some repulsive force exerted between the bodies to balance the attraction of M for f . Mr Æpinus, therefore, supposes, that every particle of tangible matter repels another particle as much as it attracts the fluid necessary for its saturation. The whole action of B on A will now be $= z \times F m - F f - M m + M f$. $F m z$ is balanced by $F f z$, and $M m z$ by $M f z$, and no excess remains on either side.

31. Æpinus acknowledges that this circumstance appeared to himself to be hardly admissible; it seeming inconceivable that a particle in A shall repel a particle in B, or tend from it, electrically, while it attracts it, or tends toward it, by planetary gravitation. We cannot conceive this; but more attentive consideration shewed him, that there is nothing in it contrary to the observed analogy of natural operations. We must acknowledge, that we see innumerable instances of inherent forces of attraction and repulsion; and nothing hinders us from referring this lately discovered power to the class of primitive and fundamental powers of nature. Nor is there any difficulty in reconciling this repulsion with universal gravitation; for while bodies are in their natural state,

27
Both ends
cannot be
neutral at
once.

28.

29

Sensible actions of electrical bodies.

30.

31
Completion of the hypothesis of Æpinus.

32
Objections answered.

state, the electric attractions and repulsions precisely balance each other, and there is nothing to disturb the phenomena of planetary gravitation; and when bodies are not in their natural electrical state, it is a fact that their gravitation is disturbed. Although we cannot conceive a body to have a tendency to another body, and at the same time a tendency from it, when we derive our notion of these tendencies entirely from our own consciousness of effort, endeavour, *conatus*, *nifus accedendi seu recedendi*, nothing is more certain than that bodies exhibit at once the appearances which we endeavour to express by these words. We can bring the north poles of two magnets near each other, in which case they recede from each other; and if this be prevented by some obstacle, they press on this obstacle, and seem to endeavour to separate. If, while they are in this state, we electrify one of them, we find that they will now approach each other; and we have a distinct proof that both tendencies are in actual exertion by varying their distances, so that one or other force may prevail; or by placing a third body, which shall be affected by the one but not by the other, &c. We do not understand, nor can conceive in the least, how either force, or how gravity, resides in a body; but the effects are past contradiction. It must be granted, therefore, that this additional circumstance of *Æpinus's* hypothesis has nothing in it that is repugnant to the observed phenomena of Nature.

N. B. It is not necessary to suppose (although Mr *Æpinus* does suppose it), that every atom of tangible matter repels every other atom. It will equally explain all the phenomena, if we suppose that every particle contains an atom or ingredient having this property, and that it is this atom alone which attracts the particles of electrical fluid. The material atoms having this property, and their corresponding atoms of fluid, may be very few in comparison with the number of atoms which compose the tangible matter. Their mutual specific action being very great in comparison with the attraction of gravitation (as we certainly observe in the action of light), all the phenomena of electricity will be produced without any sensible effect on the phenomena of gravitation, even although neither the electric fluid nor its ally, this ingredient of tangible matter, should not gravitate. But this supposition is by no means necessary.

Since we call that the natural electrical state of bodies in which they do not affect each other, and the hypothetical powers of the fluid are accommodated to this condition, we may consider any body that has more than its natural quantity as consisting of a quantity of matter saturated with fluid, and a quantity of redundant fluid superadded; and an undercharged body may be considered as consisting of a quantity of matter superadded. The saturated matter of these two bodies will be totally inactive on another body in its natural state, and will neither attract nor repel it, nor be attracted nor repelled by it; therefore the action of the overcharged body will depend entirely on the redundant fluid; and that of the undercharged body will depend entirely on the redundant matter; therefore we need only consider them as consisting of this redundant fluid or matter, agreeably to what was said in more vague terms in n^o 10. and 13. This will free us from the complicated formulæ which would otherwise be necessary for expressing all the actions of the fluid and tan-

gible matter of two bodies on each other. The results will be sufficiently particular for distinguishing the sensible action of bodies in the chief general cases: but in some particular and important cases, it is absolutely necessary to employ every term.

1. Suppose two bodies A and B, containing the quantities F' and f' of redundant fluid, it is plain that their mutual action is expressed by $F' \times f' + z$, and that it is a repulsion; for since every particle of redundant fluid in A repels every particle of redundant fluid in B with the force z ; and since F' and f' are the numbers of such particles in each, the whole repulsion must be expressed by the product of these numbers.

2. In like manner, two bodies A and B, containing the redundant matter M' and m' , will repel each other with the force $M' m' z$.

3. And two bodies A and B, one of which A contains the redundant fluid F' , and the other B contains the redundant matter m' , will attract each other with the force $F m' z$.

4. It follows from these premises, that if either of the bodies be in its natural state, they will neither attract nor repel each other; for, in such a case, one of the factors F' , or f' , or M' , or m' , which is necessary for making a product, is wanting. This may be perceived independent of the mathematical formula; for if A contain redundant fluid, and B be in its natural state, every particle of the redundant fluid in A is as much repelled by the natural fluid in B as it is attracted by the tangible matter.

The three first propositions agree perfectly with the known phenomena of electricity; for bodies repel each other, whether both are positively or both are negatively electrified, and bodies always attract each other when the one is positively and the other negatively electrified. But the fourth case seems very inconsistent with the most familiar phenomena. Dr Franklin and all his followers assert, on the contrary, that electrified bodies, whether positive or negative, always attract, and are attracted, by all bodies which are in their natural state of electricity. But it will be clearly shewn presently, that they are mistaken, and that Franklin's theory necessarily supposes the truth of the fourth proposition, otherwise two bodies in their natural state could not be neutral or inactive, as any one may perceive on a very slight examination by the Franklinian principles. It will presently appear, with the fullest evidence; and, in the mean time, we proceed to explain the action of bodies which are overcharged in some part, and undercharged in another.

Let the body B (fig. 4.) be overcharged in the part B n , and undercharged in the part B s , and let f' and m' be the redundant fluid and common matter in those parts; let A be overcharged, and contain the redundant fluid F ; let z and z' express the intensity of action corresponding with the distances of A from the overcharged and undercharged parts of B; the part B n repels A with the force $F' f' z$, while the part B s attracts it with the force $F' m' z'$: A will therefore be attracted or repelled by B, according as $F' m' z'$ is greater or less than $F' f' z$; that is, according as $m' z'$ is greater or less than $f' z$. This, again, depends on the proportion of f' to m' , and on the proportion of z to z' . The first depends on many external circumstances, which may occasion a greater or less redundancy or deficiency of electrical fluid; the second depends

33
General expression (symbolical) of the mutual action.

34.

35.

36.

37
Seeming paradox.

38
Action of a body having the fluid unequally disposed.

pendents entirely on the law of electric attraction and repulsion, or the change produced in its intensity by a change of distance. As we are, at present, only aiming at very general notions, it is enough to recollect, that all the electric phenomena, and indeed the general analogy of nature, concur in shewing that the intensity of both forces (attraction and repulsion) decreases by an increase of distance; and to combine this with that circumstance of the hypothesis which states the repulsion to be equal to the attraction at the same distance; therefore both forces vary by the same law, and we have z always greater than z' . The visible action of B on A (which, by the 3d law of motion, is accompanied by a similar action of A on B) may be various, even with one position of B, and will be changed by changing this position.

Cases of sensible repulsion.

1. We may suppose that B contains, on the whole, its natural quantity, but that part of it is abstracted from B, and is crowded into B'. This is a very common case, as we shall see presently, and it will be expressed in our formula by making $f' = m'$. In this case, therefore, we have $F f' z$ greater than $F m' z$, because z is greater than z' . A will therefore be repelled by B, and will repel it; and the repulsion will be $F f' z - F m' z$.

Of attraction.

It is evident that if A be placed on the other side of B, the appearances will be reversed, and the bodies will attract each other with the force $F f' z - F m' z$.

It is also plain, that if A be as much undercharged as we have supposed it overcharged, all the appearances will be reversed; if on the undercharged side of B, it will be repelled; and if on the overcharged side of B, it will be attracted.

Of neutrality.

2. If the redundancy and deficiency in the two portions of B be inversely proportional to the forces, so that $F' : m' = z' : z$, we shall have $f' z = m' z'$, and $m' = \frac{f' z}{z'}$. In this case these two actions balance each other, and A is neither attracted nor repelled when at this precise distance from the overcharged side of B. B may be said to be NEUTRAL with respect to A, although A and the adjoining side of B are both overcharged.

Bodies neutral at one end are more active at the other.

But if A be placed at the same distance on the other side of B, the effect will be very different: For because $m' = \frac{f' z}{z'}$, and $m' z'$ is now changed into $m' z$, and $f' z$ into $f' z'$, we have the action on A = $F \times \left(\frac{f' z}{z'} - f' z' \right)$, = $F f' \times \frac{z^2 - z'^2}{z'}$; that is, A is strongly attracted.

In like manner, f' and m' may be so proportioned, that when A, containing redundant fluid, is placed near the undercharged end of B, it shall neither be attracted nor repelled, B becoming neutral with regard to A at that precise distance. For this purpose m' must be $= \frac{f' z'}{z}$. And if A be now placed at the same distance on the other side of B, it will be repelled with the force $F f' \times \frac{z^2 - z'^2}{z}$.

Thus, when the overcharged end is rendered neutral

to an overcharged body, the other end strongly attracts it; and when the undercharged end is rendered neutral to the same body, the overcharged end strongly repels it.

Similar appearances are exhibited when A is undercharged.

These cases are of frequent occurrence, and are important, as will appear afterwards.

It is easy now to see what changes will be made on the action of B on A, by changing the proportion of f' and m' . If m' be made greater than $\frac{f' z}{z'}$, A will be attracted in the situation where it was formerly neutral; and if m' be made less, A will be repelled, &c. &c.

41.

Therefore, when we observe B to be neutral, or attractive, or repulsive, we must conclude that m' is equal to $\frac{f' z}{z'}$, or greater or less than it, &c.

We have been thus minute, that the reader may perceive the agreement between this action on a body containing redundant fluid, and the action on the superficial fluid formerly considered in n^o 21, 22, 23, 24. When these things are attended to, we shall explain, with great ease, all the curious phenomena of the electrophorus.

There is another circumstance to be attended to here, which will also explain some electrical appearances that seem very puzzling. We limited the inactivity of B to a certain precise distance of the body A. This inactivity required that m' should be $= \frac{f' z}{z'}$. If A be

42
Neutrality generally limited to a precise distance. Important information obtained from this.

brought nearer, both z and z' are increased. If they are both increased in the same proportion, the value of $\frac{z}{z'}$ will be the same as before, and the body A will neither be attracted nor repelled at this new distance. But if z increase faster than z' , we shall have $f' z$ greater than $m' z'$, and A will be repelled; and if z increases more slowly than z' , A will be attracted by bringing it nearer. The contrary effects will be observed if A be removed farther from the overcharged end of B. This explains many curious phenomena; and those phenomena become instructive, because they enable us to discover the law of electric action, by shewing us the manner in which it diminishes by a change of distance. Electricians cannot but recollect many instances, in which the motion of the electrometer appeared very capricious. The general fact is, that when an overcharged pith ball is so situated near the overcharged side of the electrophorus as to be neutral, it is repelled when brought nearer, but attracted when removed to a greater distance. This shews that z increases faster than z' when A is brought nearer to B. Now, since the bodies may be again rendered neutral at a greater distance than before, and the same appearances are still observed, it follows, that the law of action is such, that every diminution of distance causes z to increase faster than z' . We shall find this to be valuable information.

Let us, in the last place, inquire into the sensible effect on A when it also is partly overcharged and partly undercharged. This is a much more complicated case, and is susceptible of great variety of external appearances, according to the degrees of redundancy and deficiency, and according to the kind of electricity (positive or negative) of the ends which front each other.

43
Action when the fluid is unequally distributed in both bodies.

First,

First, then, let the overcharged end of A (fig. 5.) from the undercharged end of B, they being overcharged in N and n, but undercharged in S and s. Let F and f be the quantity of fluid natural to each; and let F' and f' be the redundancy in N and n, and M' and m' the deficiency in S and s. Moreover, let Z and Z' represent the intensity of actions of a particle in N on a particle in n and s; and let z and z', represent the actions of a particle in S on a particle in n and s; or, in other words, let Z, Z', z, z', represent the intensity of action between particle and particle, corresponding to the distances N s, N n, S s, S n.

Proceeding in the same manner as in the former examples, we easily see, that the action of B on A is = $\frac{F' m' Z - F' f' Z' - M' m' z + M' f' z'}{F f}$; the attrac-

tions are considered as positive quantities, having the sign + prefixed to them, and the repulsions are negative, having the sign -.

This action will be either attractive or repulsive, according as the sum of the first and last terms of the numerator exceeds or falls short of the sum of the second and third: And the value of each term will be greater or less, according to the quantity of redundant fluid and matter, and also according to the intensity of the electric action. It would require several pages to state all those possible varieties. We shall therefore content ourselves at present with stating the simplest case; because a clear conception of this will enable the reader to form a pretty distinct notion of the other possible cases; and also, because this case is very frequent, and is the most useful for the explanation of phenomena.

We shall suppose, that the redundant part of each body is just as much overcharged as the deficient part is undercharged; so that F = M', and f' = m'. In this case, the formula becomes $\frac{F' f' (Z - Z' - z + z')}{F f}$.

Here we see that the sensible or external effect on A depends entirely on the law of electric action, or the variation of its intensity by a change of distance. If the sum of Z and z' exceed the sum of Z' and z, A will be attracted; but if Z + z' be less than Z' + z, A will be repelled. This circumstance suggests to us a very perspicuous method of expressing these actions between particle and particle, so that the imagination shall have a ready conception of the circumstance which determines the external complicated effect of this internal action. This will be obtained by measuring off from a fixed point of a straight line portions respectively equal to the distances N s, N n, S s, and S n, between the points of the two bodies A and B, where we suppose the forces of the redundant fluid and redundant matter to be concentrated, and erect ordinates having the proportion of those forces. If the law of action be known, even though very imperfectly, we shall see, with one glance, of which kind the movements or tendencies of the bodies will be. Thus, in fig. 5. drawing the line Cz, take Cp = N s, Cq = N n, Cr = S s, and Ct = S n, and erect the ordinates Pp, Qq, Rr, and Tt. If the electric action be like all the other attractions and repulsions which we are familiarly acquainted with, decreasing with an increase of distance, and decreasing more slowly as the distances are greater, these ordinates will be bounded by a curve PQR'TZ, which has its convexity turned toward the axis. We

shall presently get full proof that this is the case here; but we premise this general view of the subject, that we may avoid the more tedious, but more philosophical, process of deducing the nature of the curve from the phenomena now under consideration.

This construction evidently makes the pair of ordinates Pp, Qq, equidistant with the pair Rr, Tt. Also, Pp, Rr, and Qq, Tt, are equidistant pairs. It is no less clear, that the sum of Pp and Tt exceeds the sum of Qq and Rr. For if Cz be bisected in V, and Vv be drawn perpendicular to it, cutting the straight lines PT and QR in x and y, then xv is the half sum of Pp and Tt, and yv is the half sum of Qq and Rr. Moreover, if Qm and Tn are drawn parallel to the base, we see that Pm exceeds Rr; and, in general, that if any pair of equidistant ordinates are brought nearer to C, their difference increases, and vice versa. Also, if two pairs of equidistant ordinates be brought nearer to C, each pair by the same quantity, the difference of the nearest pair will increase more than the difference of the more remote pair. And this will hold true, although the first of the remote pair should stand between the two ordinates of the first pair. If the reader will take the trouble of considering these simple consequences with a little attention, he will have a notion of all the effects that are to be expected in the mutual actions of the two bodies, sufficiently precise for our present purpose. We shall give a much more accurate account of these mathematical truths in treating the article MAGNETISM, where precision is absolutely necessary, and where it will be attended with the greatest success in the explanation of phenomena.

Now let us apply this to our present purpose. First, then, When the overcharged end of A is turned toward the undercharged end of B, A must be attracted; for Pp + Tt is greater than Qq + Rr.

Secondly, This attraction must increase by bringing the bodies nearer; for this will increase the difference between Pm and Rn.

Thirdly, The attraction will increase by increasing the length either of A or of B (the distance N s remaining the same); for by increasing the length of A, which is represented by pr or qt, Rr is more diminished than Tt is. In like manner, by increasing B, whose length is represented by pq or rt, we diminish Qq more than Tt.

On the other hand, if the overcharged end of B front the overcharged end of A, their mutual action will be

$$\frac{F' f' (-Pp + Qq + Rr - Tt)}{F f}$$

and A will be repelled, and the repulsion will increase or diminish, by change of distance or magnitude, precisely in the same manner that the attractions did. It is hardly necessary to observe, that all these consequences will result equally from bringing an apparatus similar to that represented in fig. 3. near to another of the same kind; and that they will be various according to the position and the redundancy or deficiency of the two parts of each apparatus.

If the body B of fig. 5. is not at liberty to approach toward A, nor to recede from it, and can only turn round its centre B, it will arrange itself in a certain determinate position with respect to that of A. For example, if the centre B (fig. 7.) be placed in the line passing magnetism

45
General character of the scale of electric force.

46.

47.

48.

49
Use of this picture of the forces.

50

Curious phenomena which should result from the hypothesis resembling passing magnetism.

Useful representation of the mutual forces by ordinates to a curve.

passing through S and N of the body A, B will arrange itself in the same straight line: for if we forcibly give it another position, such as $s B n$, N will attract s and repel n , and these actions will concur in putting B into the position $s' B n'$. S, however, will repel s and attract n ; and these forces tend to give the contrary position. But S being more remote than N, the former forces will prevail, and B will take the position $s' B n'$.

If the centre B be placed somewhere on the line AD, drawn through a certain point of the body NAS (which will be determined afterwards), at right angles to NAS, the body B will assume the position $n' B s'$, parallel to NAS, but subcontrary. For if we forcibly give it any other position $n B s$, it is plain that N repels n and attracts s , while S attracts n and repels s . These four forces evidently combine to turn the body round its centre, and cannot balance each other till B assume the position $n' B s'$, where n' is next to S, and s' is next to N.

Form of the electric meridian.
 If the centre of B have any other situation, such as B', the body will arrange itself in some such position as $n' B' s'$. It may be demonstrated, that if B be infinitely small, so that the action of the end of A on each of its extremities may be considered as equal, B will arrange itself in the tangent BT of a curve NB'S, such that if we draw NB, SB, and from any point T of the tangent draw TE parallel to BN, and TF parallel to B'S, we shall have BE to BF, as the force of S to the force of N. This arrangement of B will be still more remarkable and distinct if N be an overcharged sphere, and S an undercharged one, and both be insulated. We must leave it to the reader's reflection to see the changes which will arise from the inequality of the redundancy and deficiency in A or B, or both, and proceed to consider the consequences of the mobility of the electric fluid. These will remove all the difficulty and paradox that appears in some of the foregoing propositions.

51
 Consequence (fundamental) of the mobility of the fluid in the pores of bodies.
 Let the body A (fig. 4.) contain redundant fluid, and let B be in its natural state, but let the fluid in A be fixed, and that in B perfectly moveable; it is evident that the redundant fluid in A will repel the moveable fluid in B, toward its remote extremity n , and leave it undercharged in s . The fluid will be rarefied in s , and condensed in n . We need only consider the mutual actions of the redundant fluid and redundant matter. It is plain that things are now in the situation described in n° 15.: A must be attracted by B, because $f' = m'$, and z is greater than z' . The attractive force is $F' f' \times (z - z')$.

Bodies containing the natural quantity, in the natural state, attract and are attracted by electrified bodies.
 Thus we see that the hypothesis is accommodated to the phenomena in the case in which it appeared to differ so widely from it. Had the fluid been immoveable, the mutual actions would have so balanced each other that no external effects would have appeared. But now the greater vicinity of the redundant matter prevails, A is attracted by B, and, the actions being all mutual, B is attracted by A, and approaches it.

52
 And change the state of those bodies, which increases attraction.
 We have supposed that the fluid in A is immoveable; but this was for the sake of greater simplicity. Suppose it moveable. Then, as soon as the uniform distribution of the fluid in B is changed, and B becomes undercharged at s , and overcharged at n , there are forces acting on the fluid in A, and tending to change its state of distribution. The redundant matter in S at-

tracts the redundant fluid in A more than the more remote redundant fluid in n repels it, because z' is less than z . This tends to dissipate the redundant fluid of A in the nearer parts, and render N more redundant, and S less redundant in fluid than before. It is plain that this must increase their mutual action, without changing its nature. It can be strictly demonstrated, that however small the redundancy in A may be, it can never be rendered deficient in its remote extremity by the action of the unequally disposed fluid in B, if the fluid in B be no more nor less than its natural quantity. It is also plain that this change in the disposition of the fluid in A must increase the similar change in B. It will be still more rarefied in s , and condensed in n ; and this will go on in both till all is in equilibrio. When things are in this state, a particle of fluid in B is in equilibrio by the combined action of several forces. The particle B is propelled toward n by the action of the redundant fluid in A. But it is urged toward S by the repulsion of the redundant fluid on the side of n , and also by the attraction of the redundant matter on the side of s ; and the repulsion of the redundant fluid in A must be conceived as balancing the united action of those two forces residing in B.

Hence we may conclude, that the density of the fluid in B will increase gradually from s to n . It will be extremely difficult to obtain any more precise idea of its density in the different parts of B, even although we knew the law of action between single particles.

53
 General notion of the forced disposition of electric fluid in a body.

This must depend very much on the form and dimensions of B; for any individual particle sustains the sensible action of all the redundant fluid and redundant matter in it, since we suppose it affected by the more remote fluid in A. All that we can say of it in general is, that the density in the vicinity of s is less than the natural density; but in the vicinity of n it is greater; and therefore there must be some point between s and n where the fluid will have its natural density. This point may be called a Neutral or NEUTRAL point. We do not mean by this that a particle of superficial fluid will neither be attracted nor repelled in this place. This will not always be the case (although it will never be *greatly* otherwise); nor will the variation of the density in the different parts of B be proportional to the force of A on those parts. Some eminent naturalists have been of this opinion; and, having made experiments in which it appeared to be otherwise, they have rejected the whole theory. But a little reflection will convince the mathematician, that the sum of the internal forces which tend to urge a particle of fluid from its place, and which are balanced by the action of A, are *not* proportional to the variations of density, although they increase and decrease together. We shall take the proper opportunity of explaining those experiments; and will also consider some simple, but important cases, where we think the law of distribution of the fluid ascertained with tolerable precision.

If we suppose, on the other hand, that A is undercharged, the redundant matter in A will attract the moveable fluid in B, and will abstract it from the remote extremity, and crowd it into the adjacent extremity. Moreover, the fluid now becoming redundant in the nearer extremity of B, will act more strongly on the moveable fluid in A than the more remote redundant matter of B; and thus fluid will be propelled toward the remote side of A, which will become now undercharged.

charged in its nearer side, and less undercharged in its remote side than if B were taken away. This must increase the inequability of distribution of the fluid in B, and both will be put farther from their natural state; but A will never become overcharged in its remote extremity.

Things being in this state, it is plain that A and B will mutually attract each other in the same manner, and with the same force, as when A was as much overcharged as it is now undercharged.

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Electric atmosphere is not adequate to the explanation of the phenomena.

Thus, then, we see how the attraction obtains, whether A be over or undercharged. A fact which Dr Franklin could never explain to his own satisfaction; nor will it ever be explained consistently with the acknowledged principles and observed laws of mechanics by any person who employs elastic atmospheres for this purpose. It is indeed a sufficient objection to the employment of such electric or other atmospheres, that the same extent of attraction and repulsion between the particles of the atmosphere is necessary, as is employed here between the particles of the fluid residing in the body; and therefore they cease to give any explanation, even although their supposed actions were legitimately deduced from their constitution. This is by no means the case. Let any person examine seriously the *modus operandi* of the electric atmospheres employed by Lord Mahon (the only person who has written mathematically on the subject), and he will see that the whole is nothing but figurative language, without any distinct perception of what is meant by these atmospheres, as distinct from the fluid moveable in the conducting bodies, or any perception how the unequal density of these atmospheres protrudes the fluid along the conductor. Besides, it is well known that a conducting wire becomes positive at one end, and negative at the other, by the mere vicinity of an overcharged or undercharged body, and this in an instant, although it be surrounded with sealing-wax, or other non-conductors, to any thickness: in this case there can be no atmospheres to operate on the included fluid. To this we may add Dr Franklin's judicious experiment of whirling an electrified ball many times round his head, with great rapidity, by means of a silk line, without any sensible diminution of its electricity. It is not conceivable that an electric atmosphere could remain attached to the ball; nor could it be instantaneously formed round the ball, in every point of its motion, so as to be operative the moment he stopped it and tried it; for this would have exhausted or greatly diminished the electricity of the ball; whereas that sagacious philosopher affirms (and any person will find it true), that when the air is dry, he did not observe the electricity more diminished than that of another ball which remained all the while in the same place.

55
Induced electricity.

Let the overcharged body A (fig. 6.) be brought near the ends of two oblong conductors B and C in their natural state, and lying parallel to each other; the fluid will be propelled toward their remote ends N, n, where it will be condensed, while it will be rarefied in the ends S and s, adjacent to A. Both will be attracted by A, and will attract it. But the redundant fluid in NB will repel the redundant fluid in nC; and the redundant matter in SB will repel the redundant matter in sC. For this reason the bodies B and C will repel each other, and will separate; but SB attracts

nC, and NB attracts sC; and on this account the bodies should approach: but the distances of the attracting parts being greater than those of the repelling parts, the repulsions must prevail, and the bodies must really separate.

It is equally clear that the very same *sensible* appearance will result from bringing an undercharged body near the ends of B and C, although the internal motions are just the opposite to the former.

If another body D, electrified in the same way with A, be brought near the opposite ends of B and C, it will prevent or diminish the internal motions, and it should therefore prevent or diminish the external effects.

If another conducting body be brought near to the end s of C that fronts A, it will be affected as C is, and the end f will repel s; but if it be brought near the remote end, as is the case with the body F, it will attract this remote end. As the body A, containing more or less than its natural share of electric fluid, affects every other body, while they do not (when out of its neighbourhood) affect each other, it is usually said to be the electrified body, and the others are said to be electrified by it; and since these bodies, when perfect conductors, cannot retain their power of exhibiting electrical appearances (see n^o 17.), it will be convenient to distinguish this last electrical state by a particular name. We shall call it **ELECTRICITY BY POSITION, OR INDUCED ELECTRICITY**. It is induced by position with regard to the permanently electrical body.

We have supposed, in these last propositions, that the fluid was perfectly moveable in B, and, at last, also, in A: but let us examine the consequences of some obstructions to this motion. Without entering into a minute enquiry on this head, we may state the obstruction as uniform, and such that a certain small force is necessary for causing a particle of fluid to get through between two particles of the common matter, just as we conceive to happen in tenacious bodies of uniform texture (see n^o 18.).

It is evident, that when an overcharged body A (fig. 4. or 5.) is brought near such an imperfect conductor B, the fluid cannot be so copiously propelled to the remote extremity n. We may conceive the state of distribution by taking a constant quantity from the intensities of the force of A at every point of B. This circumstance alone shews us that there will not be so unequable a distribution of the fluid, and therefore *there will not be such a strong attraction between imperfect as between perfect conductors*. But besides this, we see that an incomparably longer time must elapse before things come to a state of equilibrium. Each particle of fluid employs time to overcome the obstacle to its motion, and it cannot advance till after the succeeding ones, each escaping in its turn, have again come up with the foremost. An important consequence results from this. The neutral point, where the fluid is of the natural density, will not be so far from the other body as it would have been without these obstructions; and this point will be a considerable while of advancing along the imperfect conductor. At the first approach of the overcharged electric, the near extremity of the imperfect conductor becomes a little undercharged, and the neutral point advances from the very extremity a small way, the displaced fluid being crowded a little before it, and giving way by degrees

as its foremost particles get past the obstructions. The motion forward takes place over a considerable extent at the very first; namely, in that part of the conductor where the propelling power of the neighbouring electric is just able to push a particle over the obstruction. As the propulsion goes on, the neutral point must gradually advance, and at last reach a certain distance, determined by the degree of the obstruction. It is plain, that the final accumulation at the remote end of the imperfect conductor will be less than in a perfect conductor, and the neutral point will be nearer to the other end.

57
Irregular
distribu-
tion.

There is another remarkable consequence of the obstruction. It must always happen that, at the beginning of the action, the greatest condensation will not be towards the remote extremity, but in a place much nearer to the disturbing cause. Beyond this, the condensation will diminish. As time elapses during this operation, this condensed fluid acts on the fluid beyond it by repulsion, and may do this with sufficient force to displace some of it, and render a part of the imperfect conductor deficient, with a small condensation beyond it. This may, in like manner, produce a rarefaction farther on, followed by another condensation; and this may be frequently repeated when the obstruction is very great, and the repulsion of the overcharged body very great also. This can be strictly demonstrated in some very simple cases, but the demonstration is very tedious: As the result, however, is of the first importance in the theory of electricity, and serves to explain some of the most abstruse phenomena, we wish the reader to have some stronger ground of confidence than the above bare assertion. He may observe similar effects of causes precisely similar. If we dip the end of a flat ruler into water, and if, after allowing the water to become perfectly still, we move the ruler gently along in a direction perpendicular to the face, we shall observe a single wave heap up before the ruler, and keep before it, all the rest of the water before it remaining still; but if we do the same thing in a vessel of clammy fluid, especially if the clammy part is swimming on the surface of a more perfect fluid, like a cream, we shall observe a series of such waves to curl up before the ruler, and form before it in succession; and if we have previously spotted the surface of the cream, we shall see that it is not the same individual waves that are pushed before the ruler, but that they are successively formed out of different parts of the surface, and that the particles which, at one time, form the summit of a wave, are, immediately after, at the bottom, &c. In like manner, when a cannon is fired in clear air, at no great distance, we hear a single snap; but, in a thick fog, we hear the snap both preceded and followed by a quivering noise, resembling the rushing of a fluttering wind, which lasts perhaps half a second. A slight reflection on these facts will shew that they are necessary results of the mechanical laws of such obstruction.

The consequence of this mode of action must be, that an imperfect conductor may have more than one neutral point, and more than one overcharged and undercharged portion, so that its action on distant bodies may be extremely various. The formula of n° 28. was accommodated to this case, and will be found to have very curious results. Another body may be placed in the direction of the axis, and will be attracted

at one distance, repelled when this distance is increased, and again attracted when at a still greater distance, &c. &c.

Suppose the obstruction not to be considerable: The immediate operation of the neighbouring overcharged body will be the production of an undercharged part in the adjoining extremity, an overcharged part beyond this, an undercharged portion farther on, &c. In a little while these will shift along the conductor; one after another will disappear at the farther end, and the body will have at last but one neutral point. A greater obstruction will leave the body, finally, with more than one neutral point, and their ultimate number will be greater in proportion as the obstruction to the fluid's motion is supposed greater.

Now, let the overcharged body, the cause of this unequal distribution, be removed. We have seen, n° 17. that when a body contains its natural quantity of fluid, but unequally distributed, there is a force acting on every particle, and tending to restore the original equal distribution; and that such a force remains as long as there is any inequality in this respect. If, therefore, there be no obstruction, the uniform distribution will take place immediately; for it is well known, that the speed with which electricity is propagated is immense. The elasticity, or the attractive and repulsive forces, must be very great indeed when compared with any that we know, except, perhaps, the force which impels the particles of light. The electricity, therefore, of a perfect conductor, that is, its power of acting on other bodies in the same way that an original electric acts on them, must be quite momentary, and cease as soon as the inducing cause is removed. The conductor is electrical merely in consequence of its position. Hence the propriety of our denominations. Nothing material is supposed in this theory to be communicated from the overcharged body: Nay, this theory teaches, that the sensible electricity of the overcharged body is augmented in some respects; for it becomes more overcharged in the part nearest to the conductor. Indeed it becomes less overcharged on the other end, and will act less forcibly on that side than if the conductor were away. It may be remarked here (it should have been mentioned in n° 5.) that when F is presented in the manner shewn in fig. 6. the body B becomes more strongly overcharged at the end remote from A, and more strongly undercharged at the end next to A, than when F is away. The contrary may happen, by presenting a body in the manner of E. We wish these particulars to be kept in mind. In the mean time, all these circumstances are necessary consequences of the supposition, that nothing is communicated from A to B or C. The electricity induced on perfect conductors is momentary, requiring the continual presence of a body that is electrified in some way or other.

But the case is quite otherwise in imperfect conductors. When the overcharged, or otherwise electrical body A is removed, the forces which tend to restore the uniform distribution of the fluid immediately operate, and must restore it in part. They cannot, however, do it completely: For when the force which urges any particle from an overcharged to an undercharged part, is just in equilibrio with the obstruction, it will remain, just as a number of grains of small shot may lie, uniformly mixed with a mass of clammy fluid, or,

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Induced e-
lectricity,
rendered
permanent.

Several
neutral
points.

as such fluids retain heavy mud, in a state of equable or inequable diffusion. If the resistance arise merely from the inertia of the tangible matter, there is no force so small but it will in time restore the uniform distribution. But this cannot be the case in solid bodies. Their particles exert lateral forces, by which they maintain themselves in particular situations; these must be overcome by *superior* forces.

We should therefore expect, that imperfect conductors will retain part of their inequable constitution; and, in consequence of this, their power of affecting other bodies like electrics; that is, their ELECTRICITY. For we must observe (having neglected to do it in the beginning), that the term *electricity* is as often used to express this power of producing electrical phenomena as it is used for expressing a substance supposed to be the original cause of all these appearances. It is necessary to keep this distinction in mind; because there are many phenomena which clearly indicate the transference of this cause, and they must not be confounded with others, where the exhibition of electric phenomena is evidently propagated to a distance. We must not always suppose, that when the electric appearances are exhibited in an instant at the far end of a wire $4\frac{1}{2}$ miles long, the same numerical particles of the electric fluid have moved over this space. We must distinguish those cases where this must be granted from those in which it certainly has not happened. Of these there are innumerable instances.

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Imperfect
conductors
are necessarily
idio-electrics.

We have now to observe, that by this theory the single circumstance of perfect and imperfect conducting power is sufficient for establishing the whole difference between idio-electrics and non-electrics. The idio-electrics are susceptible of excitation in various ways, and retain their electricity; and this may be done in any part of them without affecting the rest in any remarkable degree. This cannot be done in perfect conductors, plainly because they are *perfect conductors*. Any inequality of distribution of the electric fluid, which is all that is necessary for rendering them electric, is immediately destroyed by its uniform diffusion. We can have no direct proof of their incapability of excitation; but if they can be excited, they cannot shew it. We doubt, however, their excitability; because the appearances in the excitation of electrics seem to indicate, that opposite states of two bodies are necessary previous to the appearance of electricity. This is impossible in perfect conductors. By this theory, therefore, perfect conductors are necessarily non-electrics; and non-conductors are necessarily (if excitable) idio-electrics.

With respect to the particular phenomena which may be expected on the removal of the original electric; it may just be remarked, that the electric appearances of the imperfect conductor will go off in the contrary order to that of their indication. The accumulation and deficiency will diminish gradually, and the neutral point or points will gradually approach the end which had fronted the original electric. The imperfect conductor will be finally left with one or more neutral points, according to the magnitude of the obstructions, and the force which had been employed in its electrification: And their final state will be so much the more inequable, and consequently they will retain so much the greater electric powers, as they are less perfect conductors.

The last observation which we shall make on this head at present is, that whether electrified by induction, or by friction, or most other modes of excitation, the electrification will be nearly superficial in bodies which conduct very imperfectly; and bodies which are altogether impervious (if there be any such) must have the accumulation or deficiency altogether at their surface. If a glass globe be such a body, it will hardly be possible to electrify it to any depth; and all that we can expect is alternate strata of overcharged and undercharged glass. If these strata are once formed, they tend greatly to make the body retain its superficial electricity. A superficial stratum of redundant fluid, tending, by the mutual repulsion of its particles, to escape, is retained by the stratum of redundant matter immediately below it: And the almost insuperable obstruction prevents the fluid of the stratum beyond this from coming up to supply the vacancy. If we can fall on any contrivance to produce such deficient strata within the glass, we shall make it much more retentive and capable of holding fast a much greater quantity. We have already mentioned something of this in n^o 14. and we recommend the case to the attentive consideration of the reader.

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Thus have we given a sketch of the leading doctrines of this elegant theory of Mr Æpinus, all legitimately deduced from the circumstances assumed in the hypothesis concerning the *mechanical* properties of that substance which he calls *the electric fluid*. Let us now see with what success this hypothesis may be applied to account for the phenomena. It would have been more philosophical to have arranged the phenomena, and from the comparison to have deduced the hypothesis. But this would have required much more room than can be afforded in a Work like ours.

We presume, that many of our readers, namely, all such as are already conversant with electrical phenomena and with electric experiments, have seen, as we went along, the perfect agreement of the hypothesis with the various phenomena of attraction and repulsion, and all those which are usually classed under the name of electric atmospheres: and we are confident, that when they compare the consequences that should necessarily result from such a fluid with the legitimate consequences of the mechanical action of elastic atmospheres, they will acknowledge the great superiority of this hypothesis in point of simplicity, perspicuity, and analogy with other general operations of nature. To such readers it would not be necessary to state any farther comparison; but there are many who have not yet formed any distinct *systematic* view of the appearances called *electrical*. We do not know any way of giving such a view of them as by means of this hypothesis; and we may venture to say, that it will enable the student of Nature to class them all, with hardly a single exception. After which, the hypothesis may be thrown aside by the fastidious philosopher; and the useful classification, and general laws of the electric phenomena, will remain ready foundations for a more perfect theory. For the sake of such readers, therefore, we shall take a short review of those general appearances which are accompanied by attractions and repulsions, and compare them with this Æpinian theory.

We shall not at present consider the various modes of excitation, although this theory also affords much instruction

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Electrics
are only
superficially
so.

61
Comparison
of the
theory with
experiment.

struction on the subject, but confine ourselves entirely to the facts which are most immediately dependent on it, and should be employed to support or overturn it; and we shall suppose the reader acquainted with most parts of the common apparatus; such as electrometers, insulation, &c. We also presume that he knows, that when a small pith-ball has been electrified by touching a piece of glass which has been excited by rubbing with dry flannel, it will repel another body so electrified; and that balls, which have received their electricity in this manner from sealing-wax excited by the same rubber, also repel each other; but that balls, thus electrified by glass, attract those which are electrified by sealing-wax.

The following simple apparatus will serve for all the experiments which are necessary for establishing the theory:

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Apparatus
necessary
for this
compari-
son.

1. Two slender glass rods A (fig. 8.), having a brass ball B at the end, about a quarter of an inch in diameter, suspending a very small and delicate pith-ball electrometer C.

2. Some electrometers (fig. 9.), consisting of two pieces of rush pith, about four inches long, nicely suspended, and hanging parallel, and almost in contact with each other. It is proper to have them as smooth as possible, and neatly rounded at the ends, to prevent unnecessary dissipation.

3. Some pith-ball electrometers (fig. 10.), whose threads are of silk, about four inches long, and some with flaxen threads moistened with a solution of some deliquescent salt, that they may be always in a good conducting state.

4. Several brass conductors (fig. 11.), each supported on an insulating stalk and foot. They should be about an inch and half or two inches long, and about three-fourths of an inch in diameter, with round ends, and well polished, to prevent all dissipation. The foot must be so narrow as to allow them to touch each other at the ends.

5. Two balls (fig. 12.), one of glass, and the other of glass coated with sealing-wax, each furnished with an insulating handle, the other end of which may be occasionally stuck into a foot, or into the side of a block of wood, which can be slid up or down on a wooden pillar, and fixed at any height. These balls should be about three inches in diameter. They must be excited by rubbing with dry warm flannel.

6. Some little pieces of gilt card (fig. 13.), about two inches long, half an inch broad, and rounded at the ends, and made as smooth as possible. Each must have a dimple struck in the middle with a polished blunt point, so that it will traverse freely like a mariner's needle when set on a glass point, rounded in the flame of a lamp. More artificial needles may be made of some light wood, having small cork balls at the ends, all gilt and polished, and turning, in like manner, on glass stalks: also some similar needles made of sealing-wax, one end of each being black, and the other red.

The mechanical phenomena of electricity may be expressed in a few simple propositions. The most general fact that we know, and from which all the rest may be deduced, is the following:

If any body A is electrified, by any means whatever, and if another body B is brought into its neighbourhood, the last becomes electrical by position.

Set the brass conductors in a row, touching each other, as represented in fig. 11. by A, B, C; and let a pith-ball electrometer, having silk threads, be set near one end of the conductors. Excite one of the globes, by rubbing it with dry flannel. When this is brought near the end of the conductor, the pith-ball will approach the other end. But the globe must not be brought so near as to cause the pith-ball to strike against the other end. On removing the globe, the pith-ball will move off and hang perpendicularly. The same effect is produced by both globes.

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A neutral
body at-
tracte^d, be-
cause ren-
dered elec-
trical by in-
duction.

Thus the mere vicinity of the electric renders the conductor electric, and the electricity ceases on removing the globe. This is perfectly conformable to the theory, whether we suppose the fluid to be made redundant or deficient at the remote end of the conductor. If one should ascribe the approach of the pith-ball to the immediate action of the globe, it is sufficient to observe, that if the ball be suspended near the side of the conductor, it will approach the conductor, shewing that it is affected by the conductor, and not by the globe.

Let the globe be held in the position D (fig. 12.), about six inches from the conductor, and a little above the line of its axis. Take the glass rod (fig. 8.), and bring its knob into contact with the under side of the remote end *c* of the conductor. The balls of the electrometer will separate, shewing that they are electrified in the same manner, and repel each other. Slide the brass knob along the under side of the conductors quite to the end *a*. The balls will gradually collapse as the knob approaches a point near the middle of the conductors, where they will hang parallel. Passing this point, they will again separate, and most of all when the knob is at *a*. In this situation they will deviate toward the globe, and will be directed straight toward it, if it be held too near, or in the direction of the axis. This would disturb the experiment, and must be avoided. These phenomena are conformable to the account given of the disposition of the fluid in the conductor. The electrometer may be considered as making a part of the conductor; and when its threads hang parallel, it is in its natural state, having its fluid of its natural density. This, however, cannot be strictly true, according to the theory; because the balls of the electrometer must be considered as more remote from the electric, and their electrical state must correspond to a point of the conductor more remote than that where the knob of the electrometer touches it. This will be more remarkably the case as the threads are longer. Accordingly, an electrometer with very long threads will never collapse. The place of the neutral point cannot be accurately ascertained in this way. Lord Mahon imagined that its situation B was determined (in his experiments with a long conductor) to be such, that D *c* was harmonically divided in B and *a*; and he finds this to be agreeable to the result of an electric atmosphere whose density is inversely proportional to the square of the distance. But we cannot deduce this from his narration of the experiment. He gives no reason for his selection of the point D, nor tells us the form and dimensions of the electric employed, nor takes into account the action of the fluid in the long conductor. It is evident that no computation can be instituted, even on his Lordship's principles, till all this be done. We have

Lord Ma-
hon's deter-
mination of
the neutral
point not
warranted
by his ex-
planation.

always found that the neutral point was farther from the electric, in proportion as the conductor was smaller, and when the electricity was stronger; and that the differences in this respect were so very considerable, that no dependence could be had on this experiment for determining the law of action. It should be so, both according to Lord Mahon's and Mr Æpinus's theory. But to proceed with our examination:

Having touched the end *c* of the conductor with the knob of the electrometer, bring it away. The balls will continue to repel each other, and they are attracted by any body that is in its natural state. Touch the same end with the knob of the other electrometer, and bring it also away; the balls of the two electrometers will be found to repel each other: but if one has touched the conductor at *c*, and the other has touched it at *a*, the electrometers will strongly attract each other. All this is quite conformable to the theory. If the fluid has been compressed at *c*, and therefore the balls of that electrometer are overcharged, they must repel each other, and repel any other body electrified in the same way. They must attract and be attracted by any natural body. But the balls of the other electrometer having touched the conductor at *a*, must be undercharged, and the redundant fluid of the one must attract the redundant matter of the other.

If the conductor has been electrified by the vicinity of excited glass, the electrometer which touched it in the remote end *c*, will be repelled by a piece of excited glass, but attracted by excited sealing-wax. The electrometer which touched the conductor in *a* will be attracted by excited glass, and repelled by excited sealing-wax. The contrary will be observed if the conductor has had its electricity induced on it by the vicinity of the globe covered with sealing-wax. This is a complete proof that Mr Dufuy's doctrine of *vitreous* and *resinous* electricity is unfounded. Both kinds of electricity are produced in a conducting body, without any material communication, by mere juxtaposition to a body possessed of either the vitreous or the resinous electricity.

64
Constant
distinctions
of redundancy
and deficiency.

We have not yet mentioned any reasons which indicate which end of the conductor is electrical by the redundancy of electric fluid, nor is the reader prepared for seeing their force. It is generally believed that the remote end of a conductor which is electrified by glass, excited by rubbing it with flannel or amalgamated leather, is electrical by redundancy. No difference has been observed in the attractions and repulsions. But there are other marks of distinction which are constant, and undoubtedly arise from a difference in the mode of action of those of mechanical forces. If, while the excited glass globe remains at *D*, a glass mirror, foiled as usual with tin-leaf, be made to touch the remote end of the conductor, and slowly drawn transversely, so that the conductor draws a line as it were across it—this mirror being laid down with the foiled side undermost, the dust, which settles on it in the course of a day or two, will be chiefly collected along this line, somewhat in the form of the fibres of a feather. But if the conductor was rendered electrical by the globe covered with sealing-wax, the dust will be collected along this line in little spots like a row of beads. The appearances will be reversed if the mirror has been passed across the end of the conductor which is nearest to the excited

electric. In short, in whatever way the drawing point has been electrified, if it repel a ball which has touched excited glass, the line will be feathered; but if it attract such a ball, the line will be spotted. There are many ways of making this appearance much more remarkable (see ELECTRICITY, *Encycl. Sect. viii. n^o 48.*) than this; but we have mentioned it on this occasion, because the circumstances which occasion the difference, whatever it is, are the most simple possible. Nothing is communicated; and therefore the effect must arise from the unnatural state of a substance or power residing in the body. If it be a substance *sui generis*, the electric action must arise from a different distribution of this substance; from a redundancy and deficiency of it in the different portions of the conductor. Without pretending as yet to say which is redundant, we shall suppose, with Dr Franklin, that the electricity of excited glass is so; and we shall use the words *redundant* and *positive* to distinguish this electricity from the other. This is merely that we may, on many occasions, considerably abbreviate language.

The different electrical states of the different portions of the conductor may be seen in another way, which is perhaps more simple and unexceptionable than that already narrated. While the globe remains at *D*, take the two extreme pieces *A* and *C* aside; or, if only two pieces have been used, draw the remote piece farther away. Now remove the excited globe. When we examine *A* separately, we shall find it wholly negative, or undercharged, strongly repelling a ball electrified by sealing-wax, and attracting a ball electrified by glass. The other piece *C* exhibits positive electricity, attracting and repelling what *A* repelled and attracted. If only three pieces of the conductor have been employed, the middle piece *B* is generally positive; but this in a very faint degree.

If all the pieces be again joined, they are void of electricity. If, instead of such conductors, a row of metal balls, suspended by silk lines, are employed, one of them may generally be found without any sensible electricity, when separated from the rest, having been the neutral part of the row while united.

These very simple facts shew, as completely as can be wished, that if the electric phenomena depend on a fluid moveable in the pores of the body, the constitution given it by Mr Æpinus is adequate to the explanation. We may now venture to assert, that every other phenomenon of attraction and repulsion will be found in exact conformity with the legitimate consequences of this constitution of the electric fluid.

That nothing is communicated from the electric will appear still more forcibly by the following experiment: Let a conductor be rendered electrical in the way now described, and touch either extremity of it with the little electrometer, and observe attentively the divergency of its threads. Now approach its remote extremity with another conducting body, such as a single piece of those conductors, it will be rendered electrical; as may be discovered by a delicate electrometer. Observe carefully whether the electrometer in contact with the first conductor be affected:—it will generally be found to spread its threads wider. It will *certainly* be thus affected if the other conductor be very long and bulky, or touched by the hand; or if, instead of this second conductor, we approach the first with the extended
palm

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In the induction of electricity nothing is communicated. Inherent powers are excited.

point of the hand. As the second conductor was rendered electrical, so, undoubtedly, is the hand also: and its electrification has not deprived the first conductor of any of its electric power, but, on the contrary, has increased it. And this augmentation of its power is equally sensible at both ends: For an electrometer at the other end will also diverge more when the hand is brought near the remote end. This theory explains this in the most satisfactory manner. The first conductor renders the second electric, by propelling its fluid to a greater distance. The second conductor now acts on the fluid that is moveable in the first, and causes a greater accumulation in its end which is farthest from the electric; that is, renders it more electric.

Suppose that, instead of employing an excited globe of glass, we had made use of a conducting body, slightly overcharged. Thus if we employ the conductor A, overcharged, to induce electricity on C; this will produce the same general effect on our set of conductors. But if we have previously examined the force of the redundant body, by suspending a pith-ball near it, and observing its deviation from the perpendicular, we may sometimes be led to think that it has imparted something to the other body. For if the other body and the pith-ball be on opposite sides of the redundant body, the pith-ball will fall a little; indicating a diminution of electric force. But this *should happen* according to the theory; for it was shewn, in n^o 52. that the constipation in the remote end of the overcharged body will be diminished, and along with this, its action on the pith ball. We should find the electricity of the other end, next the conductor, increased, could we find an easy way of examining it; but an electrometer applied there will be too much affected by the conductor.

The same conclusions may be drawn from the following facts: Hang up a rush-pith electrometer. Approach it below with a body slightly electrified. The legs of the electrometer immediately diverge, though attracted by the electrified body. Hold the hand above the electrometer, and they will diverge still more; touch the top of it, and they spread yet farther. Hold the electrified body (very weakly electrified) above the electrometer, so that its legs may diverge a little. Hold the hand above the electrified body; the legs of the electrometer will come nearer each other.

These appearances are observed whether the electric be positive or negative. We need not take up time in explaining this by the theory, its agreement is so obvious.

Lastly, on this head, if, in place of a fixed conductor, we use one of the needles of gilt card, set on its pivot, and if we then approach it with another conducting body, in the manner represented by E and C of fig. 6. we shall observe that end of the needle to avoid the other body; but if we bring them together, in the manner represented by F and B, they will attract each other. The attraction will be greater when the body F is long; and most of all when it communicates with the ground. These phenomena are therefore in perfect conformity with the theory; but it may sometimes happen that E will attract the end of C that is nearest to A, and E will be electrified positively if A be positive. This seems inconsistent with the theory; and, accordingly, it has been adduced by Volta against Lord Mahon's account of the electrical state of a con-

ductor in a situation similar to that of C. But the theory of Æpinus shews the possibility of this case. When E is very long, or when it is held in the hand, it is rendered *much more* undercharged than the adjacent part of C; and the fluid in the remoter, but not much remoter, part of C is strongly attracted by the copious redundant matter in the near end of E, and is brought back again, and passes over into E, in the way to be described immediately. The case is rare, and it will not happen at any considerable distance from the neutral point of C. If, indeed, E touch the near end of C before A is brought near, the approach of A will cause fluid to pass into E immediately, and C will be left undercharged on the whole.

The reader, who is at all conversant with electrical experiments, will be sensible, that these experiments are delicate, requiring the greatest dryness of air, and every attention to prevent the dissipation of electricity during the performance. This, by changing the state of the conductors and electrometers, will frequently occasion irregularities. The electrometers are most apt to change in this respect, it being scarcely possible to make them perfectly smooth and free from sharp angles. It may therefore happen, that when the conductors have affected them *for some time*, by the action of the disturbing electric, the removal of this electric will not cause the electrometers to hang perpendicular; they will often be attracted by the conductors, and often repelled; but the intelligent experimenter, aware of these circumstances, will know what allowances to make.

The theory obtains a still more complete support from a comparison with similar experiments made with imperfect conductors. If, in place of the series A, B, C, of metalline conductors, we employ cylinders of glass or sealing wax, or even dry wood or marble, and electrometers with silk threads in place of the rush-pith electrometers, we shall find all the appearances to be such as the theory enables us to predict. If, for example, we use a single cylinder A of glass, we shall find that the neighbourhood of the electric D scarcely induces any electricity on A. The electrometer will hardly exhibit the smallest attraction, and its motions will be almost entirely such as arise from the immediate influence of the electric body D. A cylinder of very dry wood will be more affected by the electric D; and a circumstance of theoretical importance is very distinctly observed, namely, the gradual shifting of the neutral point. It will be found to advance along the cylinder for a very long while, when every circumstance is very favourable, the air very dry, and the wood almost a nonconductor; and its final situation will be found much nearer to the electric than in the brass conductor. Several instructive experiments of this kind may be found in a treatise published in 1783 by Dr Thomas Milner at Maidstone in Kent, entitled, "Experiments and Observations on Electricity." The author does not profess to advance any new doctrines, but only to exhibit experiments scientifically arranged for forming a system. He supports the Franklinian system as it was generally understood at that time; but is much embarrassed for the explanation of the repulsion of negative electrics. The Æpinian correction of this theory did not offer itself to his mind.

We need not go over the same ground again with imperfect conductors. It is well known that such

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The forced
disposition
of fluid is
affected by
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Phenomena
of imper-
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ductors
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roborate
the theory.

Electric
needles po-
larity and
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68

Irregula-
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dies are more weakly attracted and repelled; that the balls of an electrometer with linen threads diverge vastly more when an electrified body is held below it, than if the threads are silken: that such electrometers frequently exhibit very capricious appearances from the slow but real progress of the electricity along the threads. These anomalies will be better understood when we explain the dissipation of electricity along imperfect conductors.

69 Induced electricity of imperfect conductors is really permanent.

A very essential deduction from the theory is, that the electricity induced on an imperfect conductor must have some permanency. This is fully confirmed by experiment. But the remarkable instances of this particular cannot be produced till we be better acquainted with the methods of producing great accumulations of fluid. It is enough to observe at present, that a permanent electricity may always be observed at the junction of the conductors with their insulating stalks. The brass conductor A ceases to be electric as soon as the excited globe is removed; but the very top of the glass stalk on which it is supported will sensibly affect a delicate electrometer for a long while after. The following pretty experiment shews this permanency very distinctly. Set one of the sealing wax needles on its pivot, and place it between two insulated metal spheres of considerable size, at such a distance from both as not to receive a spark. Electrify these balls moderately, one of them positively, and the other negatively, and keep them thus electrified for some hours by renewing their electrification. The needle quickly arranges itself in the line adjoining the two spheres, just as a magnetic needle will do when placed between two magnets whose dissimilar poles front each other. Any gentle force will derange the needle; but it will vibrate like a magnetic needle, and finally settle in its former position. When this has been continued some time, that end of the needle which pointed to the positive globe will be found negative, and the other will be found positive, if examined with an electroscope. And now, if the two globes be removed, this little needle will remain electrical for entire days in dry frosty weather, and its ends will approach any body that is brought near it (taking care not to come too close); and the end which pointed to the positive globe will avoid a piece of rubbed sealing wax, but will approach a piece of rubbed glass; but the other end will be affected in the opposite way. In short, it proves an electric needle with a positive and negative pole.

If two small insulated balls are moderately electrified, and placed about six inches asunder, this needle, when carried round them, will arrange itself exactly as a magnetic needle does when carried round a magnet of the same length. If the same trial be made with the needle of gilt card, it will arrange itself in the same manner that a soft iron needle arranges itself near a magnet, but either end will turn indifferently to either globe.

Electrical meridians.

If a thin glass plate, coated with red sealing wax, be set on the positive and negative globes, and we sprinkle (from a considerable height) a fine powder of black sealing wax, and then pat the plate gently with a glass rod so as to agitate it a little, the particles of wax powder will gradually arrange themselves into curve lines, diverging from the point over one of the globes, and converging to the point over the other, precisely like the curves formed by iron-splinters sprinkled on a paper

held over a magnet. Each little rag of wax becomes electrical by position, acquires two poles, and the positive pole of one attracts the negative pole of another; and they adhere in a certain determinate position, nearly a tangent to the curve, which was mentioned in n° 50, and indicates the law of magnetic action. When in this state, if a hot brick be held over the plate till the wax soften a little, the particles of black wax will adhere to the red coating, and give us a permanent specimen of the action.

It is well known that liquid sealing wax is a conductor. The writer of this article filled a glass tube with powdered sealing wax, and melted it, and then exposed it, in its melted state, to the influence of a positive and a negative globe, hoping to make a powerful and permanent electric needle, which should have two poles, and exhibit a set of phenomena resembling those of magnetism. Accordingly he, in some measure, succeeded, by keeping the globes continually electrified for several hours, till the wax was quite cold. It had two distinct poles, and preserved this property, *even though plunged in water, and while immersed in the water*; but he was greatly disappointed as to the degree of its electricity. It just affected a sensible electrometer at the distance of six inches from either pole. It was considerably stronger than if it had not been melted during the impregnation, but by no means in the degree that he expected. It retained some electricity for about six weeks, although lying neglected among conducting bodies. After its power seemed quite extinct, he was melting it again in order to renew it. Some light fibrous things chanced to be near it. While it was softening, it became very sensibly electrical, causing these fibres to bend towards it, and even to cling to the tube. We shall see by and bye, that he was mistaken in expecting more remarkable appearances, and that the theory, when properly applied, does not promise them. Having thus established (as we think) this theory on sufficient foundations for making it a very perspicuous way of explaining the phenomena of induced electricity, we proceed to compare it with the second general fact in electricity.

PROP. II. When an insulated body B is brought very near an electrified body A, a spark is observed to pass between them, accompanied with a noise (which we shall call the electric SNAP), and B is now electrified permanently, and the electricity of A is diminished.

Although this be one of the most familiar facts in electricity, it will be proper to consider its attending circumstances in a way that connects it with what we have now learned concerning electricity by position.

Let the insulated body A (fig. 14.) be furnished with a cork-ball, hanging by a silk thread from a glass stalk connected with A; let B be fitted up in the same manner; let A be electrified weakly, and its degree of electricity be estimated by the inclination of the ball towards A: since B is not electrified, its electrometer will hang perpendicular; but when it approaches A (keeping the electrometers on the remote sides of both), its electrometer will approach it, and the electrometer of A will gradually approach the perpendicular. When the bodies are brought very near, a spark is seen between them; and, at that instant, the electrometer of

B comes

B comes much nearer to it, and that of A drops farther from it. If they be now separated, their electrometers will retain their new positions with very little change, and B will now manifest the same kind of electricity with A.

Such is the appearance when A has been but weakly electrified. Bringing B near A, the fluid in B is drawn to the remote side, if A be overcharged, or drawn to the side nearest to A, if A has been undercharged. B acts on its electrometer in consequence of the change made in the disposition of its fluid. The electrometer is attracted. In the mean time, the change made in the disposition of the fluid in B affects the moveable fluid in A. If A was overcharged, the adjacent side of B becomes undercharged, and its redundant matter, attracting the fluid in A, condenses it in the adjacent side, abstracting part of the redundant fluid from that side which is next to the pith-ball. Then the joint action of the whole redundant fluid in A on the pith-ball is diminished.

As there is now an attraction in the redundant fluid in A for the redundant matter on the adjacent side of B, it is reasonable to suppose that when this attraction, joined to the repulsion of the redundant fluid behind it, is able to overcome the attraction which connects it with the superficial particles of the matter, it will then escape and fly into B: but this will not happen gradually, but at once, as soon as the expelling force has arisen to a very considerable intensity. We cannot say what is the precise augmentation that is necessary; but we can clearly see, that however great the attraction for the adjoining particles may be, while the particle is surrounded by them on all sides, it will yield to the smallest inequality of force, because the particles before it attract as much as those behind it; but when it is just about to quit the last or superficial particles of A, a much greater force is now necessary. It can be strictly demonstrated, that when the mutual tendency is inversely as the square of the distance, the action of a particle placed immediately without a sphere of such matter is double of its action when situated in the very surface*. A *salvus* of this kind must obtain whatever be the law of electric attraction. We shall see other causes also which should prevent the escape of redundant fluid, and also its admission, till the impelling force is increased in a certain abrupt degree.

These observations must suffice at present to explain the desultory nature of this transference, if there be really a transference. That, this has happened, may be confidently inferred from the sudden diminution of the electricity of A, indicated by the sudden fall of its electrometer; but it is more expressly established, that there has been a transference by the change produced on B. It is now permanently electrified, and its electricity is of the same kind with that of A, positive or negative according as A is positive or negative. And now we are enabled to explain the third general fact in electricity.

PROP. III. When a body has imparted electricity to another, it constantly repels it, unless that other has afterwards imparted all its electricity to other bodies. This fact, from which there is no exception, is an immediate consequence of the theory. Before the transference supposed by it, B was in its natural state; after

the transference, both bodies contain redundant fluid, or redundant matter; therefore they must mutually repel.

We may now take another form of the experiment, which will be much more convincing and instructive. Let A be electrified positively, or by redundancy, and let its electrometer be attached to it by a conducting stalk, and have a flaxen thread; let this be the case also with the electrometer of B; then the appearances should happen in the following order: When A is made to approach B, the electrometer of B must gradually rise, diverging from B; because the fluid condensed on the side remote from A, and in the electrometer, will act more strongly on it than the deserted matter on the other side of B; and when the sudden transference is made, and B is wholly overcharged, its electrometer will immediately rise much higher, and must remain at that height, nearly, when A is removed. On the other hand, the electrometer attached to the remote side of A must descend, by reason of the change made in the disposition of the fluid in A by the induced electrical state of B: and when a considerable portion of the redundant fluid in A passes into B, the electrometer of A must suddenly sink much lower, and remain in that state when B is removed.

Many circumstances of this phenomenon corroborate our belief of a real transference of matter. The cause of electric action resided formerly in A alone; it now resides also in B. The larger that B is, the greater is the diminution of A's electric power, and the smaller is the power acquired by B. It perfectly resembles, in this respect, the communication of saltiness, sweetness, &c. by mixing a solution of salt or sugar with different quantities of water; and the evidence of a transference of a substance, the cause of electric attractions and repulsions, is at least as cogent as the evidence of the transference of heat, when we mix hot water with a quantity of cold, or when a hot solid body is applied to the side of a cold one. We also see so many chemical and other changes produced by this communication of electricity, that we can hardly refuse admitting that *some material substance* passes from one body to another, and, in its new situation, exerts its attractions and repulsions, and produces all their effects.

We may deduce the following corollaries; all of which are exactly conformable to the phenomena, serving still more to confirm the justness of the theory.

1. A certain quantity of what possesses these powers of attraction and repulsion is necessary for giving a determined vivacity to the appearances. Another spark must pass between the bodies, *only if they be brought still nearer*, and their electrometers must rise and fall still farther. For by the first transference of electric fluid into B, the expelling power of A is diminished, and the superior attraction of the redundant matter in the adjacent side of B is also counteracted by the repulsion of the fluid which has entered into it; therefore no more will follow unless these forces be increased, at least to their former degree. When this addition has been made to B, and this abstraction from A, their respective electrometers must be affected. All this is in perfect conformity to experience.

2. All the phenomena of communicated electricity must be more remarkable in proportion to the conducting power of the bodies. A very imperfect conductor,

Must happen abruptly.

* Opuscles de d'Alembert, t. 1. 257.

72.

73 Imparted electricity produces mutual repulsion.

74 Degrees of vivacity proportioned to the quantity imparted.

75 Communication most remarkable in conductors.

ductor, such as glass or sealing wax, will impart or receive fluid only between the very nearest parts; whereas a metalline body is instantly affected through its whole extent. This deduction is perfectly agreeable to the whole train of electric experiments. The finger receives a strong spark from a large metalline electrified body, which discharges *every part of it* of a portion of its electricity. But an excited globe, which shews, by its action on a distant body, as great a degree of electricity, will give only a very small spark; and it is found not to be affected at any considerable distance from the point of its surface from which the transference was made. The whole electricity of a perfect conductor is discharged by touching it; but a non-conductor will successively give sparks, if touched in many different parts; and it may be seen by a nice electrometer, that each contact takes away the electricity only from a very small space round it: and it is further highly deserving of notice, that some time after a spark has been obtained from a particular spot of the electric, a second spark may be obtained from it, the electricity of the neighbouring parts having been gradually diffused through it.

76
Insulation
necessary
for electric
appearan-
ces.

3. If an electrified conducting body touch any thing communicating with the ground by perfect conductors, all its electricity must disappear, and none can appear in the body touched by it; for the mass of the earth bears such an unmeasurable proportion to that of the greatest body that we can electrify, that when the redundancy or deficiency is divided between them, it must be imperceptible in both.

77.

Hence the necessity of *insulation*, as it is called, or the surrounding by non-conductors every body which we would have exhibit electric appearances. We must refer the reader to the article ELECTRICITY in the *Encycl.* for all the observations on this head, and the reasons of preference given to certain substances to be employed for insulating supports. But we must consider, in its proper place, the manner in which the electric fluid is dissipated by imperfectly insulating substances; a subject intimately connected with the theory.

78
An electrified
body attracts
& then repels
any unelec-
trified body.

4. Any unelectrified body will be first attracted by an electrified body, will touch it, and will then be repelled. The neutral body is rendered electrical by induction. It is, *in consequence of this*, attracted, comes near enough to receive a spark, or even touches it, and is then electrified by communication; and, *in consequence of this*, it is repelled. This is confirmed by an endless train of experiments. It was first taken notice of (we think) by Sir Isaac Newton. Otho Guericke, a gentleman of Magdeburgh, to whom we owe the air pump, mentions many instances of the repulsion, but did not observe that it was an universal law. Newton was so struck with it as to engage in a considerable train of experiments in the early part of his life, while meditating on the power of gravity; but even his sagacious mind did not observe the whole process of nature in his experiments. He observed, that the light bodies which rose and adhered to the rubbed plate of glass were soon after repelled by it; but did not observe that the same piece would again rise to the glass after it had touched the table. This fact is now the foundation of many experiments, which the itinerant electricians vie with each other in rendering very amusing. We may render them instructive. Take away

the middle conductor B (fig. 11.), and hang in its place a cork ball by a long silk thread. As soon as the electric body D is brought near to A, the ball is attracted by its remote end, comes into contact, is repelled by it, and attracted by the adjacent end of C, touches it, is faintly repelled by it, and again attracted by A; and the operation is repeated several times. When all has ceased, remove C, and also the electric D. C is found to have the same electricity with D, and A has the opposite electricity. The process is too obvious to need any detailed application of the theory. The cork ball was the carrier of fluid from A to C if D was electric by redundancy, or from C to A if D was undercharged. If instead of removing C when the vibrations of the ball have ceased, we bring D a little nearer, they will be renewed, and after some time will again cease. The reason is plain. The carrier ball had brought the conductor A into a state of equilibrium with the action of D. But this action is now increased, and the effects are renewed. If we now remove D, the ball will vibrate between A and C with great rapidity for a considerable time before the vibrations come to an end; and we shall find their number to be the same as before. The cause of this is also obvious from the theory. We may suppose A to be negative, and C positive. One of them will attract the ball into contact, and will repel it, having put it into an electric state opposite to that of the other conductor. It now becomes a carrier of fluid from the positive to the negative conductor, till it nearly restore both to their primitive state of neutrality.

There is frequently a seeming capriciousness in those attractions and repulsions. A pith ball, or a down feather, hung by silk, will cling to the conductor, or otherwise electrified body, and will not fly off again, at least for a long while. This only happens when those bodies are so dry as to be almost non-conductors. They acquire a positive and negative pole, like an iron nail adhering to a magnet, and are not repelled till they become almost wholly positive or negative. It never happens with conducting light bodies.

79
Irregularities
frequent—
Why.

5. It should follow from the theory, that the electric attractions and repulsions will not be prevented by the intervention of non-conducting substances in their neutral state. Accordingly, it is a fact, that the interposition of a thin pane of glass, let it be ever so extensive, does not hinder the electrometer from being affected. Also, if an insulated electric be covered with a glass bell, an electrometer on the outside will be affected. Nay, a metal ball, covered to any thickness with sealing wax, when electrified, will affect an electrometer in the same way as when naked. We cannot see how these facts can be explained by the action of electric atmospheres. It is indeed said, that the atmosphere on one side of the glass produces an atmosphere on the other; but we have no explanation of this production. If the interposed plate be a non-conductor, how does the one atmosphere produce the other? It must produce this effect by acting at a distance on the particles which are to form this atmosphere. Of what use, then, is the atmosphere, even if those atmospheres could effect the observed motions of the electrometer in consistency with the laws of mechanics? The atmospheres only substitute millions of attractions or repulsions in place of one. We must observe, however, that the motions of

80
Electric ac-
tion, like
gravitation,
is not hin-
dered by
the inter-
position of
non-con-
ductors.

of the electrometer are modified, and sometimes greatly changed, by the interposed non-conducting plate; but this is owing to the electricity induced on the plate. If the electric is positive, the adjacent surface of the plate becomes faintly negative, and the side next the electrometer slightly positive. This affects the electrometer even more than the more remote electric does. That this is the cause of the difference between the state of the electrometer when the plate is there and when it is removed, will appear plainly by breathing gently on the glass plate to damp it, and give it a small conducting power. This will make some change in the position of the electrometer. Continue this more and more, till the plate will no longer insulate. The changes produced on the electrometer's position will form a regular series, till it is seen to assume the very position which it would have taken had the plate been brass. Then, considering those changes in a contrary order, and supposing the series continued a little farther, we shall always find that it leads to the position which it would have taken when no plate whatever is interposed. We consider this as an important fact, shewing that the electric action is similar to gravitation, and that there is no more occasion for the intervention of an atmosphere for explaining the phenomena of electricity than for explaining those of gravitation.

81
Strong electricity may be excited without appearing.

6. Since non-electrics are conductors, and since electrics may be excited by friction with a non-electric, it follows, that if this non-electric be insulated, and separated from the electric, it will exhibit signs of electricity; but when they are together, there must not appear any marks of it, however strong the excitation may be. We do not pretend to comprehend distinctly the manner in which friction, or the other modes of excitation, operate in changing the connection between the particles of the fluid and those of the tangible matter; nor is this explained in any electric theory that we know: but if we are satisfied with the evidences which we have for the existence of a substance, whose presence or absence is the cause of the electric phenomena, we must grant that its usual connection with the tangible matter of bodies is changed in the act of excitation, by friction, or by any other means. In the case of friction producing positive electricity on the surface of the electric, we must suppose that the act of friction causes one body to emit or absorb the fluid more copiously than the other, or perhaps the one to emit and the other to absorb. Whichever is the case, the adjoining surfaces must be in opposite states, and the one must be as much overcharged as the other is undercharged. When the bodies (which we may suppose to have the form of plates) are joined, and the one exactly covers the other, the assemblage must be inactive; for a particle of moveable fluid, situated anywhere on the side of the overcharged plate, will be as much attracted by the undercharged surface of the remote plate as it is repelled by the overcharged surface of the near plate. The surfaces are equal, and equally electric, and act on either side with equal intensity; and they are coincident. Therefore their actions balance. The action is expressed by the formula of n° 43; namely, $F' m' \times z - z'$; and $z - z'$ is = 0, by reason of the equal distances of these surfaces from the particle of exterior fluid.

But let the plates be separated. Part, and probably the greatest part, of the redundant fluid on one of

the rubbed surfaces will fly back to the other, being urged both by the attraction of the redundant matter and the repulsion of its own particles. But the electric, being electric because, and only because, it is a non-conductor, must retain some, or will remain deprived of some, in a stratum a little within the surface. The two plates must therefore be left in opposite states, and the conducting, or non-electric plate, if insulated before separation, must now exhibit electric action.

All this is exactly agreeable to fact. We also know that electrics may be excited by rubbing on each other; and if of equal extent, and equally rubbed, they exhibit no electric powers while joined together; but when parted, they are always in opposite states. The same thing happens when sulphur is melted in a metal dish, or when Newton's metal is melted in a glass dish. While joined, they are most perfectly neutral; but manifest very strong opposite electricities when they are separated. This completely disappears when they are joined again, and reappears on their separation, even after being kept for months or years in favourable circumstances. We have observed the plates of talc, and other laminated fossils, exhibit very vivid electricity when split asunder.

82
Principles of the construction of electric machines.

Attention to these particulars enables us to construct machines for quickly exciting vivid electricity on the surface of bodies, and for afterwards exhibiting it with continued dispatch. The whirling globe, cylinder, or plate, first employed by Mr Hauksbee, for the solitary purpose of examining the electricity of the globe, was most ingeniously converted by Haufen, a German professor, into a rapid collector and dispenser of electricity to other bodies, by placing an insulated prime conductor close to that part of the surface of the globe which had been excited by friction. Did our limits give us room, we should gladly enlarge on this subject, which is full of most curious particulars, highly meriting the attention of the philosopher: But it might easily occupy a whole volume; and we have still before us the most interesting parts of the mechanical department of electricity, and shall hardly find room for what is essentially requisite for a clear and useful comprehension of it. We must therefore request our readers to have recourse to the original authors, who have considered the excitation by friction minutely. And we particularly recommend the very careful perusal of Beccaria's Dissertations on it, comparing the phenomena, in every step, with this theory of Æpinus. Much valuable information is also obtained from Mr Nicholson's Observations, of which an abstract is given in the article ELECTRICITY in the *Encyclopædia Britannica*. The Æpinian theory will be found to connect many things, which, to an ordinary reader, must appear solitary and accidental.

83
Evidences of the materiality of the electric fluid.

Seeing that this very simple hypothesis of Æpinus so perfectly coincides in its legitimate consequences with all the general phenomena of attraction and repulsion, and not only with those that are simple, but even such as are compounded of many others—we may listen, without the imputation of levity, to the other evidences which may be offered for the materiality and mobility of the cause of those mechanical phenomena. Such evidences are very numerous, and very persuasive. We have said that the transference of electricity is desultory, and that the change made in the electric state of the

communicating bodies is always considerable. It appears to keep some settled ratio to the whole electric power of the body. When the form of the parts where the communication takes place, and other circumstances, remain the same, the transference increases with the size of the bodies; and all the phenomena are more vivid in proportion. When the conductor is very large, the spark is very bright, and the snap very loud.

Snap, 1. This snap alone indicates some material agent. It is occasioned by a sonorous undulation of the air, or of some elastic fluid, which suddenly expands, and as suddenly collapses again. But such is the rapidity of the undulation, that when it is made in close vessels it does not exist long enough, in a very expanded state, to affect the column of water, supported in a tube by the elasticity of the air, for the purpose of a delicate thermometer or barometer; just as a musket ball will pass through a loose hanging sheet of paper without causing any sensible agitation.

Spark, and heat. 2. The spark is accompanied by intense heat, which will kindle inflammable bodies, will melt, explode, and calcine metals.

Chemical effects. 3. The spark produces some very remarkable chemical effects. It calcines metals even under water or oil; it renders Bolognan phosphorus luminous: It decomposes water, and makes new compositions and decompositions of many gaziform fluids; it affects vegetable colours; it blackens the calces of bismuth, lead, tin, luna cornea; it communicates a very peculiar smell to the air of a room, which is distinct from all others; and in the calcination of metals, it changes remarkably the smells with which this operation is usually accompanied: it affects the tongue with an acidulous taste; it agitates the nervous system.—When we compare these appearances with similar chemical and physiological phenomena, which naturalists never hesitate in ascribing to the action of material substances, transferable from one body, or one state of combination, to another, we can see no greater reason for hesitating in ascribing the electric phenomena to the action of a material substance; which we may call a *fluid*, on account of its connected mobility, and the *electric fluid*, on account of its distinguishing effects. We are well aware, that these evidences do not amount to demonstration; and that it is possible that the electric phenomena, as well as many chemical changes, may result from the mere difference of arrangement, or position, of the ultimate particles of bodies, and may be considered as the result of a change of modes, and not of things. But in the instances we have mentioned, this is extremely improbable.

This is therefore assumed. We therefore venture to assume the existence of this substance, which philosophers have called the *electric fluid*, as a proposition abundantly demonstrated; and to affirm, on the authority of all the above-mentioned facts, that its mechanical character is such as is expressed in Mr Æpinus's hypothesis.

We proceed, therefore, to explain the most interesting phenomena of electricity from these principles.

84
Distribution of it depends on its law of action.

We have seen that, in a perfect conductor, in its natural state, the electric fluid is uniformly distributed, and cannot remain in any other condition. We are particularly interested to know how it is distributed in an overcharged or undercharged body, and how this is affected by the circumambient non-conducting air. It

is evident that much depends on this. The tendency to escape, and particularly the tendency to transference from one body to another, must be greatest where the fluid is most condensed. We know that it tends remarkably to dissipate from all protuberances, edges, and long bodies, and that it is impossible to confine it in a body having very acute far-projecting points; and, what is more paradoxical, it is hardly possible to prevent its entering into a body furnished with a sharp point. The smallest reflection must suggest to our imagination, that a perfectly movable fluid, whose particles mutually repel, even at considerable distances, and which is confined in a vessel from which it cannot escape, must be compressed against the sides of the vessel, and be denser there than in the middle of the vessel. But in what proportion its density will diminish as we recede from the walls of the vessel, must depend on the change of electric repulsion by an increase of distance. The intensity varies in the proportion of some function of the distance, and may be expressed by the ordinates of a curve, on whose axis the distances are measured. But we are ignorant of this function. We must therefore

endeavour to discover it, by observing a proper solution of phenomena. Having made some approximation to this discovery, such as shall give rise to a *probable conjecture* concerning the function which expresses the intensity of electric repulsion, mathematics will then enable us to say how the fluid must be distributed (at least in some simple and instructive cases) in a perfectly conducting body surrounded by the air, and what will be its action on another body. Thus we shall obtain ostensible results, which we can compare with experiments. The writer of this article made many experiments with this view above 30 years ago, and flatters himself that he has not been unsuccessful in his attempts. These were conducted in the most obvious and simple manner, suggested by the reasonings of Mr Æpinus; and it was with singular pleasure that, some years after, he perused the excellent dissertation of Mr Cavendish in the Philosophical Transactions, vol. 61. where he obtained a much fuller conviction of the truth of the conclusion which he had drawn, in a ruder way, from more familiar appearances. Mr Cavendish has, with singular sagacity and address, employed his mathematical knowledge in a way that opened the road to a much farther and more scientific prosecution of the discovery, if it can be called by that name. After this, Mr Coulomb, a distinguished member of the French Academy of Sciences, engaged in the same research in a way still more refined; and supported his conclusions by some of the most valuable experiments that have been offered to the public. We shall now give a very brief account of this argument: and have premised these historical remarks; because the writer, although he had established the general conclusion, and had read an account of his investigation in a public society in 1769, in which it was applied to the most remarkable facts then known in electricity, has no claim to the more elaborate proofs of the same doctrine, which is given in some of the following paragraphs. These are but an application of Mr Cavendish's more cautious and general mathematical procedure, to the function which the writer apprehends to be sufficiently established by observation.

The most unexceptionable experiments with which we can begin, seem to be the repulsions observable between

Process for discovering this law.

tween two *small* spheres. Whatever be the law of distribution of the particles in a sphere, the general action of its particles on the particles of another sphere will follow a law which will not differ much from the law of action between two particles, if the diameters of the spheres be small in proportion to their distance from each other. The investigation was therefore begun with them. But the subject required an electrometer susceptible of comparison with others, and that could exhibit absolute measures. The one employed was made in the following manner; and we give it to the public as a valuable philosophical instrument.

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Compara-
ble electro-
meter.

Fig 15. represents the electrometer in front. A is a polished brass ball, $\frac{1}{2}$ th of an inch in diameter. It is fixed on the point of a needle three inches long, as slender as can be had of that length. The other end of the needle passes through a ball of amber or glass, or other firm non-conducting substance, about half or three-fourths of an inch in diameter; but the end must not reach quite to the surface, although the ball is completely perforated. From this ball rises a slender glass rod FEL, three inches long from F to E, where it bends at right angles, and is continued on to L, immediately over the centre of the ball A. At L is fixed a piece of amber C, formed into two parallel cheeks, between which hangs the stalk DCB of the electrometer. This is formed by dipping a strong and dry silk thread, or fine cord in melted sealing-wax, and holding it perpendicular till it remain covered with a thin coating, and be fully penetrated by it. It must be kept extended, that it may be very straight; and it must be rendered smooth, by holding it before a clear fire. This stalk is fastened into a small cube of amber, perforated on purpose, and having fine holes drilled in two of its opposite sides. The cheeks of the piece C are wide enough to allow this cube to move freely between them, round two fine pins, which are thrust thro' the holes in the cheeks, and reach about half way to the stalk. The lower part of the stalk is about three inches long, and terminates in a gilt and burnished cork-ball (or made of thin metal), a quarter of an inch in diameter. The upper part CD is of the same length, and passes through (with some friction) a small cork-ball. This part of the instrument is so proportioned, that when FE is perpendicular to the horizon, and DCB hangs freely, the balls B and A just touch each other. Fig. 16. gives a side perspective view of the instrument. The ball F is fixed on the end of the glass rod FI, which passes perpendicularly through the centre of a graduated circle GHO, and has a knob handle of boxwood on the farther end I. This glass rod turns stiffly, but smoothly, in the head of the pillar HK, &c. and has an index NH, which turns round it. This index is set parallel to the line LA, drawn through the centre of the fixed ball of the electrometer. The circle is divided into 360 degrees; and 0 is placed uppermost, and 90 on the right hand. Thus the index will point out the angle which LA makes with the vertical. It will be convenient to have another index, turning stiffly on the same axis, and extending a good way beyond the circle.

This instrument is used in the following manner: A connection is made with the body whose electricity is to be examined, by sticking the point of the connecting wire into the hole at F, till it touch the end of the

needle; or, if we would merely electrify the balls A and B, and then leave them insulated, we have only to touch one of them with an electrified body. Now, take hold of the handle I, and turn it to the right till the index reach 90. In this position, the line LA is horizontal, and so is CB; and the moveable ball B is resting on A, and is carried by it. Now electrify the balls, and gently turn the handle backwards, bringing the index back toward 0, &c. noticing carefully the two balls. It will happen that, in some particular position of the index, they will be observed to separate. Bring them together again, and again cause them to separate, till the exact position at separation is ascertained. This will shew their repulsive force in contact, or at the distance of their centres, equal to the sum of their radii. Having determined this point, turn the instrument still more toward the vertical position. The balls will now separate more and more. Let an assistant turn the long index so as to make it parallel to the stalk of the electrometer, by making the one hide the other from his view. The mathematical reader will see that this electrometer has the properties ascribed to it.

It will give absolute measures: for by poizing the stalk, by laying some grains weight on the cork-ball D, till it becomes horizontal and perfectly balanced, and computing for the proportional lengths of BC and DC, we know exactly the number of grains with which the balls must repel each other (when the stalk is in a horizontal position), in order *merely to separate*. Then a very simple computation will tell us the grains of repulsion when they separate in any oblique position of the stalk; and another computation, by the resolution of forces, will shew us the repulsion exerted between them when AL is oblique, and BC makes any given angle with it. All this is too obvious to need any farther explanation. The reason for giving the connection between A and C such a circuitous form, was to avoid all action between the fixed and the moveable part of the electrometer, except what is exerted between the two balls A and B. The needle AF, indeed, may act a little, and might have been avoided, by making the horizontal axis FI to join with A: but as it was wanted to make the instrument of more general use, and frequently to connect it with an electrical machine, a battery, or a large body, no mode of connection offered itself which would not have been more faulty in this respect. The neatest and most compendious form would have been to attach the axis FI to C, and to make CA and CB stiff metalline wires, in the same manner as Mr Brookes's electrometer is made. But as the whole of their lengths would have acted, this construction would have been very improper in the investigation of the law of electric repulsion. As it now stands, we imagine that it has considerable advantages over Mr Brookes's construction, and also over Mr De Luc's comparable electrometer, described in his *Essays on Meteorology*. It has even advantages over Mr Coulomb's incomparably more delicate electrometer, which is sensible, and *can measure* repulsions which do not exceed the 50,000 of a grain; for the instrument which we have described will measure the *attractions* of the oppositely electrified bodies; a thing which Mr Coulomb could not do without a great circuit of experiments. For instead of making the ball B *above* A, by inclining the instrument to the right hand, we may incline it to

the left ; and then, by electrifying one of the balls positively, and the other negatively, when at a great distance from each other, their mutual attraction will cause them to approach; CB will deviate from the vertical toward A ; and we can compute the force by means of this deviation.

We must remind the person who would make observations with this instrument, that every part of it must be secured against dissipation as much as possible, by varnishing all its parts, by having all angles, points, and roughnesses removed, and by choosing a dry state of the air, and a warm room ; and, because it is impossible to prevent dissipation altogether, we must make a previous course of experiments, in a variety of circumstances, in order to determine the diminution per minute corresponding to the circumstances of the experiments that are to be made with further views.

We trust that the reader will accept of this particular account of an instrument which promises to be of considerable service to the curious naturalist ; and we now proceed with an account of the conclusions which have been drawn from observations made with it.

Here we could give a particular narration of some of the experiments, and the computations made from them ; but we omit this, because it is really unnecessary. It suffices to say, that the writer has made many hundreds, with different instruments, of different sizes, some of them with balls of an inch diameter, and radii of 18 inches. Their coincidence with each other was far beyond his expectation ; and he has not one in his notes which deviate from the medium $\frac{1}{3}$ th of the whole force, and but few that have deviated $\frac{1}{12}$ th. The deviations were as frequently in excess as in defect. His custom was to measure all the forces by a linear scale, and express them by straight lines erected as ordinates to a base, on which he set off the distances from a fixed point ; he then drew the most regular curve that he could through the summits of these ordinates. This method shews, in the most palpable manner, the coincidence or irregularity of the experiments.

The result of the whole was, that the mutual repulsion of two spheres, electrified positively or negatively, was very nearly in the inverse proportion of the squares of the distances of their centres, or rather in a proportion somewhat greater, approaching to $\frac{1}{x^2.06}$. No difference was observed, although one of the spheres was much larger than the other ; and this circumstance enables us to make a considerable improvement on the electrometer. Let the ball A be made an inch in diameter, while B is but $\frac{1}{4}$ th of an inch. This greatly diminishes the proportion of the irregular actions of the rest of the apparatus of the whole force, and also diminishes the dissipation when the general intensity is the same.

When the experiments were repeated with balls having opposite electricities, and which therefore attracted each other, the results were not altogether so regular, and a few irregularities amounted to $\frac{1}{6}$ th of the whole ; but these anomalies were as often on one side of the medium as on the other. This series of experiments gave a result which deviated as little as the former (or rather less) from the inverse duplicate ratio of the distances ; but the deviation was in defect as the other was in excess.

We therefore think that it may be concluded, that the action between two spheres is exactly in the inverse

duplicate ratio of the distance of their centres, and that this difference between the observed attractions and repulsions is owing to some unperceived cause in the form of the experiment.

It must be observed also, that the attractions and repulsions, with the same density and the same distances, were, to all sense, equal, except in the forementioned anomalous experiments. The mathematical reader will see that the above-mentioned irregularities are imperfections of experiment, and that the gradations of this function of the distances are too great to be much affected by such small anomalies. The indication of the law is precise enough to make it worth while to adopt it, in the mean time, as a hypothesis, and then to select, with judgment, some legitimate consequences which will admit of an exact comparison with experiment, on so large a scale, that the unavoidable errors of observation shall bear but an insignificant proportion to the whole quantity. We shall attempt this: and it is peculiarly fortunate that this observed law of action between two spheres gives the most easy access to the law of action between the particles which compose them ; for Sir Isaac Newton has demonstrated (and it is one of his most precious theorems), that if the particles of matter act on each other with a force which varies in the inverse duplicate ratio of the distances, then spheres, consisting of such particles, and of equal density at equal distances from the centre, also act on each other with forces varying in the same proportion of the distances of their centres. He demonstrates the same thing of hollow spherical shells. He demonstrates that they act on each other with the same force as if all their matter were collected in their centres. And, lastly, he demonstrates, that if the law of action between the particles be different from this, the sensible action of spheres, or of hollow spherical shells, will also be different (see *Principia*, I. Prop. 74, &c. also *ASTRONOMY*, *Encycl.* 307.)

Therefore we may conclude, that the law of electric attraction and repulsion is similar to that of gravitation, and that each of those forces diminishes in the same proportion that the square of the distance between the particles increase. We have obtained much useful information from this discovery. We have now full confirmation of the propositions concerning the mutual action of two bodies, each overcharged at one end and undercharged at the other. Their evidence before given amounted only to a reasonable probability ; but we now see that the curve line, whose ordinates represent the forces, is really convex to the abscissa, and that $Z + z'$ is always greater than $Z' + z$; from which circumstance all the rest follows of course.

Let us now enquire into the manner in which the redundant fluid, or redundant matter, is distributed in bodies ; the proportion in which it subsists in bodies communicating with each other ; the tendencies to escape ; the forces which produce a transference, &c. &c.

In the course of this enquiry, a continual reference will be made to the following elementary proposition :

Let ABD (fig. 17.) be the base of a cone or pyramid, whose vertex is P, and axis PC ; and let *abd* be another section of it by a plane parallel to the base ; let these two circles, or similar polygons, consist of matter or fluid of equal and uniform density ; and let P be a particle of fluid or matter ; the attraction or repulsion of this particle for the whole matter or fluid in the figure ABD is equal to its attraction or repulsion for the

Attractions and repulsions are equal at equal distances.

86
Spheres, when electrified, repel with a force proportional to $\frac{1}{x^2}$;

87
And attract according to the same law.

89
Electric action is inversely as the square of the distance.

90
Disposition of such fluid when redundant or deficient.

91
Lemma.

the whole matter or fluid in *abd*. For the attraction for a particle in *ABD* is to the attraction for a particle similarly placed in *abd* as Pc^2 to PC^2 ; and the number of particles in *ABD* is to that of those in *abd* as PC^2 to Pc^2 ; therefore the whole attraction for *ABD* is to that for *abd* as $Pc^2 \times PC^2$ to $PC^2 \times Pc^2$, or in the ratio of equality.

Cor. 1. The same will be true of the action of plates of equal thickness and equal density; or, in general, having such thickness and density as to contain quantities of matter or fluid proportional to their areas.

2. The action of all such sections made by parallel planes, or by planes equally inclined to their axis, are equal.

3. The tendency of a particle *P* to a plane, or plate of uniform thickness and density, and infinitely extended, or to a portion of it bounded by the same pyramid, is the same, at whatever distance it be placed from the plate, and it is always perpendicular to it.

4. This tendency is proportional to the density and thickness of the plate or plates jointly.

It is only in two or three simple cases that we can propose to state with precision what will be the disposition and action of the electric fluid in bodies; but we shall select those that are most instructive, and connected with the most remarkable and important phenomena.

Let *AadD* (fig. 18.) and *EebH* represent the sections of a part of two infinitely extended parallel plates (which we shall call *A* and *E*), consisting of solid conducting matter, in which the electric fluid can move without any obstruction, but from which it cannot escape.

First, Let them be both overcharged, *A* containing the quantity *r* of redundant fluid, and *E* containing the quantity *s*, and let *r* be greater than *s*.

The fluid will be disposed in the following manner:

1. There will be two strata, *AabB* and *GgbH*, adjoining to the remote surfaces, in each of which the quantity $\frac{r+s}{2}$ will be crowded together as close as possible.

2. Adjoining to the interior surface (that is, the surface nearest to *E*) of the plate *A*, there will be a stratum *CcdD*, containing the quantity $\frac{r-s}{2}$ crowded together.

3. The adjacent side of *E* will have a stratum *EefF*, just sufficient for containing the quantity $\frac{r-s}{2}$ at its natural density. This stratum will be entirely exhausted of fluid.

4. The spaces *BbcC* and *FfgG* will be in their natural state.

For a particle of fluid in the space *BbcC* is urged in the direction *ad* by the force $\frac{r+s}{2}$ (*n*° 91, 3.),

and in the direction *da* by the force $\frac{r-s}{2}$, therefore it is, on the whole, urged in the direction *ad* with the force *s*, which will balance the repulsion of the redundant fluid in the other plate. A particle of fluid in the space *FfgG* is repelled in the direction *be* by a force $\frac{r+s}{2}$ by the fluid in *GgbH*, and it is attracted in the same direction by the redundant matter in *EefF*,

with the force $\frac{r-s}{2}$. These make a force *r* which balances the repulsion *r* of the other plate. No other disposition will be permanent; for if a particle be taken out from either stratum *AabB* or *CcdD* into the space between them, the repulsion from that stratum which it quitted is lessened, and the repulsion of the opposite stratum, joined to that of the other plate, will drive it back again. The same thing holds with respect to the fluid in the other plate.

Cor. 1. If the two plates be equally overcharged, all the redundant fluid will be crowded on the remote surfaces, and the adjacent surfaces will be in the natural state.

In the *second* place, let the plates be undercharged, and let *r* be the fluid wanting in *A*, and *s* the fluid wanting in *E*, and let *s* be greater than *r*; then,

1. The strata adjoining to *Aa* and *Hb* will be completely exhausted of fluid, and the redundant matter in each will be such as would be saturated by $\frac{r+s}{2}$.

2. The stratum *CcdD* will contain redundant fluid $\frac{s-r}{2}$, crowded close.

3. The stratum *EefF* will be deprived of fluid, and the quantity abstracted is $\frac{s-r}{2}$.

4. The spaces *BbcC* and *FfgG* are in the natural state.

The demonstration is the same as in the former case.

Thirdly, Let *A* be overcharged, and *E* undercharged, *A* containing the redundant fluid *r*, and *E* wanting the fluid *s*; and let *r* be greater than *s*. Then,

1. The strata *AabB* and *GgbH* contain the redundant fluid $\frac{r-s}{2}$, crowded close.

2. The stratum *CcdD* contains the quantity $\frac{r+s}{2}$, crowded close.

3. The stratum *EefF* is exhausted, and wants the quantity $\frac{r+s}{2}$.

4. The rest is in the natural state.

Cor. 2. If the redundant fluid in *A* be just sufficient to saturate the redundant matter in *E*, the two remote surfaces will be in their natural state, all the redundant fluid in *A* being crowded into the stratum *CcdD*, and all the redundant matter being in *EefF*.

This disposition will be the same, whatever is the distance or thickness of the plates, unless the redundant fluid in *A* be more than can be contained in the whole of *E* when crowded close.

When the two plates are overcharged, the fluid presses their remote surfaces with the force $\frac{r+s}{4}$, and

would escape with that force if a passage were opened. It would enter the remote surfaces of two undercharged plates with the same force; and, in either case, it would run from the inner surface of one to the adjacent surface of the other, with the force $\frac{r-s}{4}$.

If one be overcharged and the other undercharged, fluid would escape from the remote surface with the force

93.

94
When they are undercharged,

95

When they are in opposite states,

96.

97
Pressure and tendency to escape.

92
Disposition in parallel plates,

When both are overcharged,

force $\frac{r-s^2}{4}$, and would run through a canal between them with the force $\frac{r+s^2}{4}$.

Mutual actions.

They repel or attract each other with the force $\frac{r+s^2}{4}$ according as they are both over or undercharged, or as one is overcharged and the other undercharged.

This example of parallel plates, infinitely extended, is the simplest that can be supposed. But it cannot obtain under our observation; and in all cases which we can observe, the fluid cannot be uniformly spread in any stratum, but must be denser near the edges, or near the centre, as they are overcharged or undercharged.

98
Disposition in a sphere.

Let ABD (fig. 19.) represent a sphere of perfectly conducting matter, overcharged with electric fluid, which is perfectly moveable in its pores, but cannot escape from the sphere. Let it be surrounded by conducting matter saturated with moveable fluid. It is required to determine the disposition of the fluid within and without this sphere.

Sir Isaac Newton has demonstrated (*Princ. I. 70.*) that a particle p , placed anywhere within this sphere, is not affected by any matter that is without the concentric spherical surface pqr in which itself is situated, therefore not affected by what is between the surfaces ABD and pqr . He also demonstrates, that the matter within the surface pqr acts on the particle p in the same manner as if the whole of it were collected in the centre C.

Hence it follows, that the redundant fluid will be all condensed as close as possible within the external surface of the sphere, forming a shell of a certain minute thickness, between the spherical surfaces ABD and abd ; and all that is within this (that is, nearer the centre C) will be in its natural state.

With respect to the distribution of the fluid in the surrounding matter, which we suppose to be infinitely extended, we must recollect that this shell of condensed redundant fluid repels any external particle of fluid in the same manner as if all were collected at C. Hence it is evident, that the fluid in the surrounding matter will be repelled, and, being moveable, it will recede from this centre; and there will be a space all round the sphere ABD which is undercharged, forming a shell between the concentric surfaces ABD and $\alpha\beta\delta$. This shell will contain such a quantity of redundant matter, that its attraction for a particle of fluid is equal to the repulsion of the shell of fluid crowded internally on the surface ABD. All beyond this surface $\alpha\beta\delta$ will be in its natural state; for this redundant matter acts on a particle of fluid, situated farther from the centre, in the same manner as if all this redundant matter were collected in the centre C. So does the redundant fluid in the condensed shell. Therefore their actions balance each other, and there is no force exerted on any particle of fluid beyond this deficient shell. This deficient shell will not affect the fluid in the sphere abd by Newton's demonstration. No other disposition will be permanent. But farther: This undercharged shell must be completely exhausted: for a particle of fluid placed between ABD and $\alpha\beta\delta$ will be more repelled by the fluid in the crowded shell within the surface ABD, than it is attracted by the redundant matter of its own shell that is less remote from the centre; and

it is not affected by what is more remote from the centre. Therefore the fluid without the sphere ABD cannot be in equilibrio, unless the shell between ABD and $\alpha\beta\delta$ be not only rarefied, but altogether exhausted of fluid.

If the sphere be undercharged, the space between ABD and abd will be entirely exhausted of fluid, and there will be a shell $\alpha\beta\delta$ of redundant matter surrounding the sphere. All within abd , and all without $\alpha\beta\delta$, will be in its natural state. It is unnecessary to repeat the steps of the same demonstration.

This valuable proposition is by the Hon. Mr Cavendish.

This would be the disposition in and about a glass globe filled and surrounded with an ocean of water, and having redundant fluid within it, on the supposition that glass is impervious to the electric fluid. But it would not affect an electrometer, even supposing that the movements of the electrometer could be effected under water. Suppose the globe of water to be surrounded with air, and that the fluid is disposed in both in the manner here described; it will be perfectly neutral in its action on any electrometer situated in the air. But, by reason of the almost total immobility of the fluid in pure dry air, this state cannot soon obtain; and, till it obtain, the condensed shell within the glass must repel the fluid in an electrometer more than the partially rarefied shell of air, which surrounds the glass, attracts it. By the gradual retiring of the fluid in the surrounding air from the globe, the attraction of the deserted matter will come nearer to equality with the repulsion of the condensed shell within the glass, and the globe will appear to have lost fluid. Yet it may retain all the redundant fluid which it had at the first. Therefore we are not to imagine that a body similar to this globe has no redundant electric fluid, or only a small quantity, because we observe it inactive, or nearly so.

Thus we see, as we proceed, that the Æpinian theory is adequate to the explanation of the phenomena. But we see it much more remarkably in a very familiar and amusing experiment, usually called the ELECTRIC WELL. See ELECTRICITY, *Encycl. Sect. x. 4.*

To see it in perfection, make a glass vessel of globular shape, with a narrow mouth, sufficiently wide, however, to admit an electrometer suspended to the end of a glass rod of a crooked form, so that the electrometer can be presented to any part of the inside. Smear the outside of the globe with some transparent clammy fluid, such as syrup. Set it on an insulating stand (a wine glass), and electrify it positively. Hold the electrometer near it, anywhere without, and it will be strongly affected. Its deviations from the perpendicular (if the ball of the electrometer has also been electrified) will indicate a force inversely as the square of the distance from the centre of the globe, pretty exactly, if the thread of the electrometer is of silk. Now let down the electrometer into the inside of the globe. It will not be affected in any sensible degree, nor approach or avoid any body that is lying within the globe. The electrometer may be held in all parts of the globe, and when brought out again, is perfectly inactive and neutral. But if the balls of the electrometer be touched with a wire, while hanging free within the globe, they will, on withdrawing the wire, repel each other; and when taken out, they will be found negatively electrified.

99
Consequences of this disposition.

100
Verified by the phenomena. Electric Well explained.

hed. The experiment succeeds as well with a metal globe; nay, even although the mouth be pretty wide; in which case, there is not a perfect balance of action in every direction. The electrometer may be made to touch the bottom of the globe, or anywhere not too near the mouth, without acquiring any sensible electricity; but if we touch the outside with the electrometer, it will instantly be electrified and strongly repelled. Deep cylinders, and all round vessels with narrow mouths, exhibit the same faintness of electricity within, except near the brims, although strongly electric without; and even open metal cups have the interior electricity much diminished.

Reflecting on this valuable proposition of Mr Cavendish, we see clearly why an overcharged electric is only superficially so; and that this will be the case even although we attempt to accumulate a great quantity of electricity in it, by melting it in a thin glass globe, and electrifying it while liquid, and keeping up the accumulating force till it becomes quite cold. The present writer, not having considered the subject with that judicious accuracy that Mr Cavendish exerted, had hopes of producing a powerful and permanent electric in this way, and was mortified and puzzled by the disappointment, till he saw his mistake on reading Mr Cavendish's dissertation.

These observations also point out a thing which should be attended to in our experiments for discovering the electricity excited in the spontaneous operations of nature, as in chemical composition and decomposition, congelation, fusion, evaporation, &c. It has been usual to put the substances into glass, or other non-conducting vessels, or into vessels which conduct very imperfectly. In this last case especially, the very faint electricity which is produced, instantly forms a compensation to itself in the substance of the vessel, and the apparatus becomes almost neutral, although there may have been a great deal of electricity excited. It will be proper to consider, whether the nature of the experiment will admit of metalline vessels. In the experiments on metalline solutions, the best method seems to be, to make the vessel itself the substance that is to be dissolved.

For similar reasons we may collect, without a more minute examination, that bodies of all shapes, when overcharged, will have the redundant fluid much denser near the surface than in the interior parts; and denser in all elevations, bumps, projections, angles, and near the ends of oblong bodies; and that, in general, the quantity of redundant fluid, or redundant matter, will be much more nearly proportional to the surfaces of bodies than to their quantities of matter. All this is fully proved by experience. The experiment of the electrified chain is a very beautiful one. Lay a long metal chain in an insulated metal dish furnished with an electrometer. Let one end be held an inch or two above the coil by a silk thread. Electrify the whole, and observe the divergency of the electrometer; then, gradually drawing up the chain from the coil, the electrometer will gradually fall lower, and lowering the chain again will gradually raise it.

We now see with how little reason Lord Mahon concluded that the point of his conductor, observed to be neutral, corresponded with his theory; namely, one of the media of a harmonic division. We see no reason

for beginning the computation at the extremity of the prime conductor. It certainly should not have been from the extremity. Had the prime conductor been a single globe, it should have begun from the centre of this globe. If it was of the usual form, with an outstanding wire, terminated by a large ball, the action of the body of the conductor should certainly have been taken into the account. In short, almost any point of the long conductor might have been accommodated to his Lordship's theory.

We might now proceed to investigate the distribution of the electric fluid in bodies exposed to the action of others, and particularly in the oblong conductors made use of in our preparatory propositions. The problem is determinate, when the length and diameter of cylindrical conductors are given; but even when the electric employed for inducing the electricity is in the form of a globe, we must employ functions of the distances that are pretty complex, and oblige us to have recourse to second fluxions. The mutual actions of two oblong conductors, of considerable diameters, give a problem that will occupy the first mathematicians; but which is quite improper for this scanty abstract. Nor is a minute knowledge of the disposition of the fluid of very important service. We may therefore content ourselves with a general representation of the state of the fluid in the following manner, which will give us a pretty distinct notion how it will act in most cases:

Let A (fig. 20.) be an overcharged sphere, and BC a conducting cylindrical or prismatic body; draw bc parallel to BC, and erect perpendiculars $Bb, Cc, Pp,$ &c. to represent the equable density of the fluid, when the conductor is in its natural state; but let $Bd, Cr, Ps,$ &c. represent the unequal densities in its different points, while in the vicinity of the overcharged sphere. These ordinates must be bounded by a line dnr , which will cut the line bc in the point n of the perpendicular, drawn from the neutral point N of the conductor. The whole quantity of fluid in the conductor is represented by the parallelogram $BCcb$; which must therefore be equal to the space $BCrnd$: the redundant fluid in any portion CP or PN is represented by the spaces $crtp$, or tpn ; and the redundant matter, or deficient fluid, in any portion BQ, is represented by $bdwq$. The action of this body on any body placed near it, depends entirely on the area contained between this curve line and its axis bc . The only circumstance that we can ascertain with respect to this curve is, that the variations of curvature in every point are proportional to the forces exerted by the sphere A; and are therefore inversely as the squares of the distances from A. This property will be demonstrated by and bye. The place of n , and the magnitude of the ordinates, will vary as the diameter of the conductor varies. We shall consider this a little more particularly in some cases which will occur afterwards. We may consider the simplest case that can occur; namely, when the conductor is, like a wire, of no sensible diameter, nay, as containing only one row of particles.

Let AE (fig. 21.) be such a slender conducting canal; and let $Bb, Cc, Ee,$ &c. represent the density of the fluid which occupies it, being kept in this state of inequable density by the repulsion for some overcharged body. A particle in C is impelled in the direction CE by all the fluid on the side of A, and in the

101
Electric bodies are only superficially so.

104.

General representation of the disposition of the fluid.

Cautions in certain experiments.

102
Electricity more nearly proportional to the surface than to the quantity of matter.

103.

In a very slender canal the fluid must be almost equally distributed.

direction CA by all the fluid on the side of E. The moving force, therefore, arises from the difference of these repulsions. When the diameter of the canal is constant, this arises only from the difference of density. The force of the element adjacent to E may therefore be expressed by the excess of D d above C c, and the action at the distance CD jointly. Therefore, drawing $\beta c e$ parallel to AE, this force of the element E will be expressed by $\frac{d^{\delta}}{c^{\beta^2}} x$, repelling the particle in the direction CA. If CF be taken equal to CD, the force of the element at F will be expressed by $\frac{f^{\rho}}{c^{\beta^2}} x$, or $\frac{f^{\rho}}{c^{\beta^2}} x$, also impelling the particle in the direction CA. The joint action of these two elements therefore is $\frac{d^{\delta} + f^{\rho}}{c^{\beta^2}} x$.

If b c e were a straight line, we should have $d^{\delta} + f^{\rho}$ always proportional to c^{δ} ; and it might be expressed by $m \times c^{\delta}$; m being a number expressing what part of c^{δ} the sum of d^{δ} and f^{ρ} amounts to (perhaps $\frac{1}{10}$ th, or $\frac{1}{20}$ th, or $\frac{1}{30}$ th, &c.). But in the case expressed in the figure, d^{δ} does not increase so fast as c^{δ} , and f^{ρ} increases faster than c^{δ} . However, in the immediate neighbourhood of any point C, we may express the accelerating force tending towards A by $\frac{m c^{\delta}}{c^{\beta^2}} x$, without any sensible error; that is, by $m \frac{x}{c^{\beta}}$; that is, by

the fluxion of the area of a hyperbola HD'G, having CC' and CK for its asymptotes; and the whole action of the fluid between F and D, on the particle C, will be expressed by the area C'CDD'H. Hence it follows, that the action of the smallest conceivable portion of the canal immediately adjoining to C on both sides, or the difference of the actions of the two adjoining elements, is equal to the action of all beyond it. This shews, that the state of compression is hardly affected by any thing that is at a sensible distance from C; and that the density of the fluid, in an indefinitely slender canal, is, to all sense, uniform. The geometer will also see, that the second fluxion of D d is proportional to the force of the distant body. We learn, therefore, so much of the nature of the curve b c e.—(Coulomb).

We are now in a condition to examine the communication of electricity by means of conducting canals (which is one of the most important articles of the study,) having found that the fluid, in a very slender canal, is very nearly of uniform density throughout.

There can be no doubt but that, if a body B (fig. 22.) be overcharged or undercharged, any other body C, which communicates with it by a conducting canal, will also be overcharged or undercharged. It is as evident, that if a body, in any state of electricity, be in the neighbourhood of an overcharged or undercharged body A, while it communicates with C by a canal leading from the side most remote from A, fluid will be driven from B into C, or abstracted from C into B.

It is not, however, so clear, that when the canal leads from the side nearest to A (as in fig. 23.), fluid will be driven from B into C. We conceive the fluid to be moveable in the body and in this canal, but not to escape from it. Its motion, therefore, in this case, should, in the opinion of Mr Cavendish, resemble the

running of water in a syphon by the pressure of the air. While the repulsion of the redundant fluid in A allows the bend of the syphon nearest to A to retain fluid, a current should take place from B along the short leg, in consequence of the superior action on the fluid in the long leg. But if the repulsion of A can drive the fluid out of the bend between B and F, Mr Cavendish thinks, that it does not appear that fluid will come up from B in opposition to the repulsion of A, and then run along to D. But fluid does not move, in either of these cases, on the principle of a syphon; because there is nothing to hinder the fluid from expanding in the part EDF. And we are rather disposed to think, that it will always move from B, over the bend, to C; For even if the fluid can be completely driven out of the bend EF, it must be done by degrees, and the fluid in the long leg will, from the very beginning of the action of A, be more moved from its place than that in the short leg; and therefore will yield to the compression, which acts transversely, and, by thus yielding more toward F than toward E, the fluid will rush through the contracted part, and go into C. We do not say this with full confidence; but are thus particular, on account of an important use that may be made of the experiment. For if the body A be undercharged, fluid will certainly be attracted from C, and pass over the bend into B, however great the action of A may be. Perhaps this may be so contrived, therefore, as to decide the long agitated question, *Whether the electricity of excited glass be plus or minus?* If it be found that this apparatus, being presented to the rubber of an electrical machine, diminishes the positive electricity of C, and increases that of B; but that, presenting the same apparatus to the prime conductor, makes little change—we may conclude, that the electricity of the prime conductor is positive. We have tried the experiment, paying attention to every circumstance that seemed likely to insure success; but we have always found hitherto, that the apparatus was equally affected by both electricities.

We must now consider the action of electrified bodies on the canals of communication; because this will give us the easiest method of ascertaining the proportion in which the expelling fluid is distributed between them. For when two bodies communicate by a canal, and have attained a permanent state, we must conceive that their opposite actions on the fluid moveable along this canal are in equilibrio, or are equal. This will generally be a much easier problem than their action on each other, since we have seen a little ago, that the fluid in a slender canal is of uniform density very nearly. A very few examples of the most important of the simple cases must suffice.

Therefore let AC a (fig. 24.) represent the edge of a thin conducting circular plate, to which the slender canal CP is perpendicular in the centre. It is required to determine the action of the matter or fluid, uniformly spread over this plate, on the fluid moveable in the canal PC?

1. Required the action of a particle in A on the fluid in the whole canal? Join AP; and call CP x, AP y, and AC r; and let f express the intensity of action at the distance 1, or the unit of the scale on which the lines are measured.

The action of A on P, in the direction AP, is $\frac{f}{g^2}$. This,

Proposal for discovery of redundancy of fluid.

Action of a circular canal.

106
Communication and transference by canals.

107
By crooked canals.

109.

This, when estimated in the direction CD, is reduced to $\frac{f}{y^2} \times \frac{x}{y}$; and is therefore $= f \frac{x}{y^3}$. Therefore the fluxion of the action, in the direction CP, on the whole canal, is $f \frac{x}{y^3} \dot{x} = f \frac{y \dot{y}}{y^3}$ (because $x : y = \dot{y} : \dot{x}$) $= f \times \frac{y}{y^2}$. The variable part of the fluent is $= f \frac{1}{y}$, and

the complete fluent is $= f (C - \frac{1}{y})$, where C is a constant quantity, accommodated to the nature of the case. Now, the action must vanish when the canal vanishes, or when $x = 0$, and $y = r$. Therefore $C - \frac{1}{r} = 0$, and $C = \frac{1}{r}$; and the general expression of the action is f

$(\frac{1}{r} - \frac{1}{y})$, $= f \frac{y - r}{ry}$, expressing the action of a particle in the circumference of the plate on the fluid in the whole canal CP.

2. Required the action of the plate, whose diameter is A a, on the particle P?

Let a represent the area of a circle, whose diameter is = 1. Then $a r^2$ is the area of the plate, and $2 a r \dot{r}$ is the fluxion of this area: because $r : y = \dot{y} : \dot{r}$, $2 a r \dot{r}$ is $= 2 a y \dot{y}$. Therefore the fluxion of the action of the plate on the particle P is $f \times 2 a y \dot{y} \times \frac{x}{y^3} = 2 f a x \times \frac{y}{y^2}$. The fluent of this has for its variable part

$2 f a x \times \frac{1}{y}$ (for when the particle P is given, x does not vary). This is $= 2 f a \times \frac{x}{y}$. To complete this

fluent, we must add a constant quantity, which shall make the fluent = 0 when the particle P is at an infinite distance; and therefore when $x = y$. Therefore $\frac{y}{y} - \frac{x}{y} = 0$, or $1 - \frac{x}{y} = 0$, or $C = 1$; and the complete fluent for the whole plate is $2 f a (1 - \frac{x}{y})$.

The meaning of this expression may not occur to the

reader: For $1 - \frac{x}{y}$ is evidently an abstract number; so is a. Therefore the expression appears to have no reference to the size of the plate. But this agrees with the observation in n^o 91. where it was shewn that, provided the angle of the cone or pyramid remained the same, the magnitude of the base made no change in its attraction or repulsion for a particle in the vertex.

It will appear by and bye, that $1 - \frac{x}{y}$ is a measure or function of a certain angle of a cone.

Cor. If PC be very small in proportion to AC, the action is nearly the same as if the plate were infinite:

For when the plate is infinite, $\frac{x}{y}$ is = 0, and the action is = 1, whatever is the distance (see n^o 91-93.) Therefore, when x is very small in comparison of r, and consequently of y, $1 - \frac{x}{y}$ is very nearly = 1.

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3. To find the action of the plate on the whole column?

The fluxion of this must be $= 2 f a \times (1 - \frac{x}{y}) \dot{x}$,

or $2 f a (\dot{x} - \frac{x \dot{x}}{y})$, or $2 f a \times (\dot{x} - \dot{y})$; because $\dot{y} = \frac{x \dot{x}}{y}$. The fluent of this has for its variable part $2 f a \times (x - y)$. A constant quantity must be added, which shall make it = 0 when the column = 0; that is, when $y = r$, and $x = 0$; that is, $C - r = 0$, and $C = r$. Therefore the complete fluent is $= 2 f a (x + r - y)$.

Thus we have arrived at a most simple expression of the attraction or repulsion of a plate for such a column, or for portions of such a column. And it is most easily constructed geometrically, so as to give us a sensible image of this action of easy conception and remembrance. It is as follows: Produce PC till CK = CA, and about the centre P describe the arch AI, cutting CK in I. Then $2 f a \times IK$ is evidently the geometrical expression of the attraction or repulsion. This is plainly a cylinder, whose radius is a unit of the scale, and whose height is twice IK.

In like manner, by describing the arch Ai round the centre p, we have $2 f a \times i K$ for the action of the plate on the small column Cp; and $2 f a \times Ii$ is the action of the plate on the portion Pp.

The general meaning of the expression $2 f a \times IK$ is, that the action of the whole plate on the column PC is the same as if all the fluid in the cylinder $a \times 2 IK$, were placed at the distance 1 from the acting particle.

From this proposition may be easily deduced some very useful corollaries by the help of the geometrical construction.

1. If PC be very great in comparison with AC, the action is nearly the same as if the column were infinitely extended; for in this case IK is very nearly = CK, the difference being to the whole nearly as AC to twice AP.

2. If, in addition to this last condition, another column pC be very small in comparison of AC, then the action on PC is to that on pC very nearly as pC to AC. For it will appear that $i K : IK = pC : AC$ very nearly. It is exactly so when $CP : CA = CA : Cp$; and it will always be in a greater proportion than that of pC to IK.

This will be found to be a very important observation.

The redundant fluid has hitherto been supposed to be uniformly spread over the plate: but this cannot be; because its mutual repulsion will cause it to be denser near the circumference. We have not determined, by a formula of easy application, what will be the variation of density. Therefore let us consider the result of the extreme case, and suppose the whole redundant fluid to be crowded into the circumference of the plate, as we saw that it must be on the surface of a globe.

In this case, the action on the fluid in the canal will be $f a (r - \frac{r^2}{y})$. For the area of the plate is $a r^2$, and

112
2. On the whole canal.

113
Geometrical expression of these actions.

114.

115
Important corollary.

116
Action of a circumference on a canal.

110
1. On a single particle in the canal.

111.

the action of a particle in the circumference on the whole canal was shewn (n^o 109.) to be $f \left(\frac{y-r}{ry} \right)$. Therefore the action of the whole fluid crowded into the circumference is $f a r^2 \times \frac{y-r}{ry} = f a r \frac{y-r}{y}$. It may be represented as follows: Describe the quadrant *CbBE*, cutting *AP* and *A*p** in *B* and *b*. Draw *BD* and *bd* parallel to *PC*. Then *PB* = *y* - *r*, and *DC* = $\frac{y-r}{y}$. Therefore the action is represented by *f* multiplying a cylinder, whose radius is 1 and height is *DC*. In like manner, *dC* is the height of the cylinder corresponding to the column *pC*, and *Dd* the height corresponding to *P*p**.

117. *Cor. 1.* When *CP* is very great in comparison with *CA*, the point *D* is very near to *A*, and *I* is very near to *C*, and *CD* is to *IK* nearly in the ratio of equality. In this case the action of the fluid, uniformly spread over the plate, is nearly double of the action of the same fluid crowded round the circumference; for they are as cylinders, having the same bases and heights in the ratio of 2 *IK* to *DC*, which is nearly the ratio of 2 to 1.

118. 2. On the other hand, when the column *pC* is very short, the action of the fluid spread uniformly over the plate is to its action, when crowded round the circumference, nearly in the ratio of 4 *AC* to *pC*. For these actions are in the ratio of $2fa \times iK$ to $1fa \times dC$, or as 2 *iK* to *dC*, or nearly as 2 *pC* to *dC*, or more nearly as 2 *bd* to *dC*. But *Cd*:*bd* = *bd*:*bA* + *Ad*, or nearly = *bd*:2 *CA*. Therefore *Cd*:2 *bd* = *pC*:4 *CA* nearly.

119. Hence we see that the action on short columns is much more diminished by the recess of the redundant fluid toward the circumference than that on long columns. Therefore, any external electric force which tends to send fluid along this canal, and from thence to spread it over the plate, will send into the plate a greater quantity of fluid than if the fluid remained ultimately in a state of uniform distribution over its surface; and that the odds will be greater when the canal is short.

120
Equivalent
centre of
action.

Lastly, on this subject. If *KL* be taken equal to *AP*, or *PL* be equal to *KI*, the repulsion which all the fluid in the plate, collected in *K*, would exert on the fluid in the canal *CL*, is equal to the repulsion which the same fluid, constricted in the circumference, would exert on the column *CP*. For we have seen that the action of a particle in *A*, on the whole column *PC*, when estimated in the direction *PC*, is $\frac{y-r}{yr}$; and it is well known that the action of a particle in *K* for the column *CL* is $\frac{I}{KC} - \frac{I}{KL}$, or $\frac{1}{r} - \frac{1}{y} = \frac{y-r}{yr}$. Therefore the action of the whole fluid, collected in the circumference, on the column *CP*, is equal to that of the same fluid, collected in *K*, on the columns *CL*.

121. *Cor. 1.* If the column *CP* is very long in proportion to *AC* or *KC*, the actions of the fluids in these two different situations are very nearly the same. The action of the fluid collected in *K* exceeds its action when collected in *A* only by its action on the small and remote column *LP*. The action of all the fluid collect-

ed at *K* on the column *CP*, is easily had by taking *Cl* = *KP*. It is equal to the action of the same fluid placed in *A* on the column *Cl*.

Cor. 2. The action of all the fluid uniformly spread, exerted on the column *CP*, is to the action of the same fluid collected in *K*, exerted on the column *CL*, as 2 *IK* to *CD*. 122.

If the column *CP* is very great in proportion to *AC*, the half breadth of the plate, the action in the first case is very nearly double of the action in the other case, and is exactly in this proportion if *CP* is of infinite extent. 123.

Cor. 3. If *CNO* be a spherical surface or shell of the same thickness and diameter as the plate *Aa*, and containing redundant fluid of the same uniform density, the action of this fluid on the column *CL* is double of the action of the fluid uniformly spread over the plate on the column *CP*, and quadruple of the action of the fluid collected in the circumference: for the action is the same as if all were collected in the centre *K*, and the surface of the sphere is four times that of the plate, and therefore they are as *IK* to 2 *CD*. 124.

Let us now consider the comparative actions of different plates or spheres on the canals.

If two circular plates, *DE*, *de* (fig. 25.), or two spherical shells, *ABO*, *abo*, of equal diameters and thickness with the plates, and containing redundant fluid of equal density, communicate with infinitely extended straight canals *OP*, *op*, passing through their centres perpendicular to their surfaces, also containing fluid uniformly distributed and of equal density—the repulsions will be as the diameters. For the repulsion of the spherical surfaces is the same as if all the fluid were collected at their centres; and the repulsion of the fluid uniformly spread over the surfaces of the plates is double of its repulsion if collected at the centres of these spheres; it follows, that the repulsions of the plates are proportional to those of the spheres. But because the repulsion of a plate whose radius is *r* was shewn to be = $2a \times r + x - y$, and when the column is infinitely extended, *x* is equal to *y*, and $r + x - y = r$, it follows, that the repulsions of the plates are as $2a \times R$ and $2a \times r$, or proportional to their diameters. Therefore the repulsions of the spheres are in the same proportion. 125.

Cor. 1. If the canals are very long in proportion to the diameters of the plates or spheres, the repulsions are nearly in the same proportion. 126.

Cor. 2. But as the lengths of the canals diminish, the repulsions approach to equality; for it was shewn, that when the canal was very small, the repulsion was to that for an infinite column as the length of the canal to the radius of the plate. Therefore if the radius of the greater plate be (for example) double of that of the smaller, and the little column be $\frac{1}{3}$ th of the radius, it will be $\frac{1}{3}$ th of the radius of the smaller plate. Now $\frac{1}{3}$ th of half the repulsion is equal to $\frac{1}{6}$ th of the double repulsion. Also, in the case of the spheres, the repulsion of a particle at the surface is as the quantity of fluid directly, and as the square of the radius inversely; but when the density is the same in both shells, the quantity is as the surface, or as the square of the radius. Therefore the repulsions are equal. 127.

Cor. 3. If the density of the fluid in two spherical shells be inversely as the diameters, the repulsions for an infinitely

128 infinitely extended column of fluid are equal; for each repels as if all the fluid was collected in the centre. Therefore, if the density, and consequently the quantity, be varied in any proportion, the repulsion will vary in the same proportion. The repulsions will now be as the diameters; as $CO \times \frac{I}{CO}$ to $co \times \frac{I}{co}$, or in the ratio of equality.

129 Or if the quantity of redundant fluid be as the diameters. *Cor. 4.* When the quantities of redundant fluid in two spheres are proportional to their diameters, their repulsions for an infinitely extended canal are equal: for if this redundant fluid is confipated in the surfaces of the spheres, as it always will be when they consist of conducting matter, the densities are as the diameters inversely, because the surfaces are as the squares of the diameters. Therefore, by the last corollary. their actions on an infinitely extended canal are equal. But in spheres of nonconducting matter it may be differently disposed, in concentric shells of uniform density. This makes no change in the action on the fluid that is without the sphere, because each shell acts on it as if it were all collected in the centre. Therefore the repulsions are still equal.

130 Two spheres overcharged in this proportion are in equilibrium if communicating by a very long canal. *Cor. 5.* Two overcharged spheres, or spherical shells, OAB, *oab* (fig. 26.), communicating by an infinitely extended canal of conducting matter, contain quantities of redundant fluid proportional to their diameters; for their actions on the fluid in the interjaent canal must be in equilibrium, and therefore equal. This will be the case only when the quantities of fluid are in the proportion of their diameters.

When the canals are very long in proportion to the diameters of the spheres, the proportion of the quantities of redundant fluid will not greatly differ from that of the diameters.

131. *Cor. 6.* When the spheres of conducting matter are thus in equilibrium, the pressures of the fluid on their surfaces are inversely as their diameters; for the repulsion of a particle at the surface is the same with the tendency of that particle from the centre of the sphere, the actions being mutual. Now this is proportional to the quantity of redundant fluid directly, and to the square of the distance from the centre inversely, that is, to the diameter directly, and to the square of the diameter inversely, that is, to the diameter inversely.

Hence it follows, that the tendency to escape from the spheres is inversely as the diameter, all other circumstances being the same: for in as far as the escape proceeds from mere electric repulsion, it, must follow this proportion. But there are evident proofs of the co-operation of other physical causes. We observe chemical compositions and decompositions accompanying the escape of electric fluid, and its influx into bodies: we are ignorant how far, and in what manner, these operations are affected by distance. Boscovich shews most convincingly, that the action of a particle (of whatever order of composition), on external atoms and particles, is surprisingly changed by a change in the distance and arrangement of its component atoms. A confipation, therefore, to a certain determined degree and lineal magnitude, may be necessary for giving occasion to some of those chemical operations that accompany, and perhaps occasion, the escape of the electric fluid. If this be the case (and it is demonstrable to be possible, if the operations of Nature be owing to attrac-

tions and repulsions), the escape *must* be desultory. It is actually fo; and this confirms the opinion.

THE public is indebted to Mr Cavendish for the preceding theorems on the action of spheres and circular plates. He has given them in a more abstract and general form, applicable to any law of electric action which experience may warrant. We have accommodated them to the inverse duplicate ratio of the distances, as a point sufficiently established; and we hope that we have rendered them more simple and perspicuous. We have availed ourselves of Mr Coulomb's demonstration of the uniform density in the canal, without which the theorems could not have been demonstrated. The minute quantity of the fluid in the canal can have no sensible effect on the disposition or proportion of the fluid in the plates or spheres.

It may be thought that the last corollary, respecting the equilibrium of two spheres, is not agreeable to hydrostatical principles, which require the equality of the two forces which balance each other at the orifices of the slender cylindric canal; whereas, in that corollary, the forces at the extremities of the canal are inversely as the diameters of the spheres or plates. This would be a valid objection, if the compressing forces acted only on the extremities of the canals; but they act on every particle through their whole length. It is not, therefore, the pressure at one end of the canal that is in equilibrium with the pressure at the other end, by the interposition of the fluid. It is the pressure at one end, together with the sum of all the intermediate pressures in that direction, that is in equilibrium with all the pressure in the opposite direction. The pressures at the ends are only parts of the whole opposite pressures; they are the first in each account. In this manner a slender pipe, having a ball at each end, may be kept filled with mercury, while lying horizontal, if the air in each ball is of equal density. But if it be raised perpendicular to the horizon, it cannot remain filled from end to end, unless the air of the ball below be made so elastic by condensation, that its pressure on the lower orifice of the pipe exceed the pressure of the air in the upper ball on the other orifice by a force equal to the weight of the mercury, that is, to the aggregate of the action of gravity on each particle of mercury in the pipe. Therefore the repulsions of the spheres that we are speaking of are in equilibrium by the intervention of the fluid in the canal, in perfect consistency with the laws of hydrostatical pressure.

Mr Cavendish has pursued this subject much farther, and has considered the mutual action of more than two bodies, communicating with each other by canals of moveable fluid uniformly dense. But as we have not room for the whole of his valuable propositions, we selected those which were elementary and leading theorems, or such as will enable us to explain the most important phenomena. They are also such, as that the attentive reader will find no difficulty in the investigation of those which we have omitted.

Mr Cavendish's most general proposition is as follows: ¹³² General proposition with respect to the state of communicating bodies. When an overcharged body communicates, by a canal of *very great* length, straight or crooked, with two or more similar bodies, also at a very great distance from each other, and all are in electric equilibrium, and consequently

This proposition agrees with hydrostatical laws.

consequently

consequently each body overcharged in a certain determined proportion, depending on its magnitude, if any two of these bodies are made to communicate in the same manner, their degrees of electricity are such, that no fluid will pass from one to the other, their mutual actions on the fluid in this canal being also in equilibrio. He brings out this by induction and combination of the single cases, each of which he demonstrates by means of the following theorem :

133
It is indif-
ferent whe-
ther the ca-
nal be
straight or
crooked.

The action of an overcharged sphere ACB (fig. 25.) on the fluid in the whole of a canal $dffP$ that is oblique, tending to impel the fluids in the direction of that canal, is equal to its action on the fluid in the whole of the rectilineal canal CP. Let bi be a minute portion of the straight canal, and fd the portion of the crooked canal which is equidistant from the centre C of the sphere; draw the radii Cf , Cd , and the concentric arches bf , id , cutting fC in g ; and draw ge perpendicular to fd ; the force acting on ib , impelling it toward P, may be represented by bi . The same force acting on df , in the direction cf , must therefore be expressed by gf . This, when estimated in the direction of the canal df , is reduced to ef ; but it is exerted on each particle of df . Now $df:gf = gf:ef$, and $df \times ef = gf^2 = gf \times bi$; therefore the whole force on df , in the direction df , is equal to the force on ib , in the direction ib . Hence the truth of the proposition is manifest.

We beg the curious reader to apply this to the case in hand, and he will find that the most complicated cases may all be reduced to the simple ones which we have demonstrated to be strictly true when the bodies are spheres or plates, and the canals infinitely long, and which are very nearly true when the canals are *very long*, and the bodies similar: And we now proceed to one compound case more, which includes all the most remarkable phenomena of electricity.

134
Curious
and very
important
case of four
plates.

Let HK, AB, DF, and LM (fig. 27.), be four parallel and equal circular plates, two of which, HK and AB, communicate by a canal GC of indefinite extent, joining their centres, and perpendicular to their planes; let DF and LM be connected in the same manner, and let the two canals be in one straight line; let the plate HK be overcharged, and the plate LM just saturated. It is required to determine the disposition and proportion of the electric fluid in the plates which will make this condition of HK and LM possible and permanent, every thing being in equilibrio?

The plate HK being overcharged, and communicating with AB, AB must be overcharged in the same manner; and being also equal to HK, it must be overcharged in the same degree, containing an equal quantity of redundant fluid disposed in the same manner. To simplify the investigation, we shall first suppose that the redundant fluid is uniformly spread over the surfaces of both.

When the plates HK and AB are in this state, let the plates DF and LM be brought near them, as is represented in the figure, CE being the distance of the centres of AB and DF. It is evident that the redundant fluid in AB will act on the natural moveable fluid in DF, and drive some of it along the canal EN, and render LM overcharged. Take off this redundant fluid in LM. This will diminish or annihilate the repulsion which it was beginning to exert on the canal

EN; therefore more fluid will come out of DF, and again render LM overcharged. The redundant fluid in LM may again be taken off, in less quantity than before, as is plain. Do this repeatedly till no more can be taken off. But this will undoubtedly render DF undercharged, and it will now contain redundant matter. This will act on the fluid in the canal GC, and abstract it from G; therefore fluid will come out of HK into AB. HK will be less overcharged than before, and AB will be more overcharged. But the now increased quantity of redundant fluid in AB will act more strongly on the moveable fluid in DF, and drive more out of it. This will leave more redundant matter in it than before, and this will act as before on the fluid in the canal GC. This will go on, by repeatedly touching LM, till at last all is in equilibrio. Or this ultimate state may be produced at once by allowing LM to communicate with the ground. And now, in this permanent state of things, HK contains a certain quantity of redundant fluid; AB contains a greater quantity; DF contains redundant matter; and LM contains its natural quantity. The demand of the problem therefore is to determine the proportion of the redundant fluid in HK to that in AB, and the proportion of the redundant fluid in AB to the deficiency of fluid in DF. The dynamical considerations which determine these proportions are, *1st*, The repulsion of the redundant fluid in AB, for the fluid in the canal EN, must be precisely equal to the attraction of the redundant matter in DF for the same fluid in the canal; for LM, being saturated, is neutral. *2d*, The repulsion of the redundant fluid in HK, for the whole fluid in the canal GC, must balance the excess of the repulsion of the redundant fluid in AB above the attraction of the redundant matter in DF for the same.

Let the redundant fluid in AB be = f .
the redundant matter in DF = m .
the redundant fluid in HK = f .

Because HK and AB are equal, there can be no doubt but that the fluid in those plates would be similarly disposed; and it is highly probable, that if AB be very near DF, the redundant fluid in AB, and the redundant matter in DF, will also be disposed nearly in the same manner. This will appear plainly when we consider with attention the forces acting between a very small portion of AB and the corresponding portion of DF. The probability that this is the case is so evident, that we apprehend it unnecessary to detail the proofs. We shall afterwards consider some circumstances which shew that the disposition in the three plates will (though nearly similar) be nearer to a state of uniform distribution than if only AB and HK had been in action. Assuming therefore this similarity of distribution, it follows, that their actions on the fluid in the canals will be similar; and nearly proportional to their quantities.

Therefore let r be to n as the repulsion of the fluid in AB, for the fluid that would occupy CE, is to its repulsion for the fluid in EN or CG.

Then the action of AB on EN is $f \times n - r$, and the action of DF on EN is $m n$; therefore, because the plate LM is inactive, the actions of AB and DF on EN must balance each other, and $f \times n - r = m n$, and $m = f \times \frac{n - r}{n}$.

The

The repulsion of f for the fluid in CG is fn . The attraction of m for it is $m \times n - 1$; and because $m = f \times \frac{n-1}{n}$, the attraction of m for the fluid in CG is $f \times \frac{n-1}{n} \times n - 1$. Therefore the repulsion of f

is to the attraction of m as fn to $f \times \frac{n-1}{n}$, or as fn^2 to $f \times n - 1$, or as n^2 to $n - 1$. Call the repulsion of f , and the attraction of m , a .

We have $r : a = n^2 : n - 1$
and $r : r - a = n^2 : n^2 - (n - 1)^2 = n^2 : 2n - 1$.

Therefore, because the repulsion of F is equal to this excess of r above a , we have $n^2 : 2n - 1 = f : F$, and $F = f \frac{2n-1}{n^2}$, or $f = F \frac{n^2}{2n-1}$. Therefore, if n^2 is much greater than $2n - 1$, the quantity of redundant fluid in AB will be much greater than the quantity in HK .

135
Prodigious accumulation of redundant fluid;

Now, when the electric action is inversely as the square of the distance, and EC is very small in comparison with AC , we have seen (n^o 115.) that $1 : n$ nearly $ly = CE : CA$, or that n is nearly $\frac{AC}{EC}$. When this is the case, and consequently n is a considerable number, we may take the number $\frac{n^2}{2n}$ or $\frac{n^2}{2n-1}$ without any

great error. In this case f is equal to $F \times \frac{n}{2}$ very nearly. Suppose CA to be six inches, and CE to be $\frac{1}{16}$ th of an inch; this will give $n = 120$, and $f = 60F$; or, more exactly, $F = \frac{n^2}{2n-1} = \frac{14,400}{239}$; $= 60\frac{1}{4}$. If, instead of the plate HK , we employ a globe of the same diameter, f will be but half of this quantity, or $f = F \times \frac{n}{4}$ (n^o 123, 124.)

136
And evacuated:

It also appears, that when the plates AB and DF are very near to each other, and consequently n a large number, the deficiency in DF is very nearly equal to the redundancy in AB . In the example now given, m is $\frac{59}{60}$ of f , being $= f \times n - 1$.

137
Yet no very sensible appearance.

Yet this great deficiency in DF does not make it electrical on the side toward LM . It is just so much evacuated that a particle of fluid at its surface has no tendency to enter or to quit it.

Lastly, this great quantity of fluid collected in AB does not render it more electrical than HK .

In general, things are in the condition treated of in n^o 22, 23, &c.

The attentive reader will readily see, that this account of the apparatus of four plates is only an approximation to the condition that readily obtains under our observation. Our canals are not of indefinite length, nor occupied by fluid that is distributed with perfect uniformity; nor is the fluid uniformly spread over the surface of the plates. He will also see, that the real state of things, as they occur in our experiments, tends to diminish the great disproportion which this imaginary statement determines. But when the canals are very long in comparison with the diameters of the plates,

and AB is very near to DF , the difference from this determination is inconsiderable. We shall note these differences when we consider the remarkable phenomena that are explained by them.

In the mean time, we shall just mention some simple consequences of the present combination of plates.

Suppose AB touched by a body. Electric fluid will be communicated; but by no means all the redundant fluid contained in AB : only as much will quit it as will reduce it to a neutral state, if the body which touches it communicates with the ground; that is, till the attraction in the redundant matter in DF attracts the fluid on the remote side of AB as much as the redundant fluid left in AB repels it. When this has been done, DF is no longer neutral; for the repulsion of AB for the fluid in EN is now diminished, and therefore the attraction of DF will prevail. If we now touch DF , it may again become neutral with respect to EN ; but AB will now repel again the fluid in CG , and again be electric on that side by redundancy. Touching AB a second time takes more fluid from it, and DF again becomes electric by deficiency, and attracts fluid on that side.—And thus, by repeatedly touching AB and DF alternately, the great accumulation of fluid in AB may be exhausted, and the nearly equal deficiency in DF may be made up.

138
Method of destroying this great accumulation: By degrees;

But this may be done in a much more expeditious way. Suppose a slender conducting canal abd brought very near to the outsides of the plates, the end a being near to A , and the end d to D . The vicinity of a to A causes the fluid in ab to recede a little from a by the repulsion of the redundant fluid in AB . This will leave redundant matter in a , which will strongly attract the redundant fluid from A , and a may receive a spark. But the consequence, even of a nearer approach of the fluid to the outward surface of A , will render the corresponding part of DF more attractive, and the retiring of fluid from a along ab will push some of its natural fluid toward d ; and thus A becomes more disposed to give out, and a to take it in, while d is disposed to emit, and D to attract. Thus every circumstance favours the passage of the whole, or almost the whole, redundant fluid to quit AB at A , to go along abd , and to enter into DF at D .

139
2. All at once.

It is plain that there must be a strong tendency in the fluid in AB to go into DF , and that the plates must strongly attract each other. A particle of fluid situated between them tends toward DF with a force, which is to the sole repulsion of AB nearly as twice the redundant fluid in it to what it would contain if electrified to the same degree while standing alone.

140
The plates strongly attract each other.

With this particular and remarkable case of induced electricity, we shall conclude our explanation of Mr \AA pinus's Theory of Electric Attraction and Repulsion. The reader will recollect, that we began the consideration of the disposition of the electric fluid in bodies, in order to deduce such legitimate consequences of the hypothetical law of action as we could compare with the phenomena.

These comparisons are abundantly supplied by the preceding paragraphs, particularly by n^o 74, 75, 76; by n^o 130, and by n^o 134.

141
Method of examining the validity of this theory.

Let a smooth metal sphere be electrified positively in any manner whatever, and then touch it with a small

one in its natural state. The redundant fluid is divided between them in a proportion which the theory determines with accuracy. By the theory also the redundant fluid in both acts as if collected in the centre. Therefore the proportion of the repulsions is determined. These can be examined by our electrometer. But as this mensuration may be said to depend on the truth of the theory, we may examine this independent of it. Let the balls be equal. Then the redundant fluid is divided equally between the bodies, whatever be the law of action. Therefore observe the electrometer, as it is affected by the electrified body, both before and after the communication. This will give the positions of the electrometer which correspond to the quantities 2 and 1.

142
Graduation
of electro-
meter.

Take off the electricity of one of the balls by touching it, and then touch the other ball with it. This will reduce to $\frac{1}{2}$ the original quantity $\frac{1}{2}$, and therefore to $\frac{1}{4}$ th of the original quantity. This will determine the value of another position of the electrometer. In like manner, we obtain $\frac{1}{8}$ th, $\frac{1}{16}$ th, &c. &c. Then, by touching a ball containing 1 with a ball containing $\frac{1}{2}$, we get a position for $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, &c. Proceeding in this way, we graduate our electrometer independently of all theory, and can now examine the electricity of bodies with confidence. The writer of this article took this method of examining his electrometer, not having then seen Mr Cavendish's dissertation, which gives another mode of measurement. He had the satisfaction of observing, in the first place, that the positions of the instrument, which unquestionably indicated 1, $\frac{1}{2}$, $\frac{1}{3}$, &c. were precisely those which should indicate them if electric repulsion be inversely as the squares of the distances. Having thus examined the electrometer, it was easy to give to balls any proposed degree of electricity, and then make a communication between balls of very different diameters. The electrometer informed us when the repeated abstractions by a small ball reduced the electricity of a large ball to $\frac{1}{2}$, $\frac{1}{3}$, &c. This shewed the proportion of electricity contained in balls of different diameters. This was also found to be such as resulted from an action in the inverse duplicate ratio of the distances.

143. Long after this, Mr Cavendish's investigation pointed out the proportion of the redundant electric fluid in balls of different sizes joined by long wires; in n° 130, &c. these were examined—and found to be such as were so indicated by the electrometer.

144. And, lastly, the mode of accumulating great quantities of fluid by means of parallel plates, gave a third way of confronting the hypothetical law with experiment. The argument was no less satisfactory in this case; but the examination required attention to particulars not yet mentioned, which made the proportions between the fluid in HK and AB (fig 27.) widely different from those mentioned in the preceding paragraphs. These circumstances are among the most curious and important in the whole study, and will be considered in their place.

145
The law of
electric ac-
tion is well
determi-
ned.

We rest therefore with confidence on the truth of the law of electric action, assumed by us as a principle of explanation and investigation. It is quite needless and unprofitable to give any detail of the numerous experiments in which we confronted it with the phenomena. The scrupulous reader will get ample satisfac-

tion from the excellent experiments of Mr Coulomb with his delicate electrometer. He will find them in the Memoirs of the Academy of Sciences of Paris for 1784, 1785, 1786, and 1787. Some of them are of the same kind with those employed by the writer of this article; others are of a different kind; and many are directed to another object, extremely curious and important in this study, namely, to discover how the electric fluid is disposed in bodies; and a third set are directed to an examination of the manner in which the electric fluid is dissipated along imperfect conductors.

But we have already drawn this article to a great length, and must bring it to an end, by explaining some very remarkable phenomena, namely, the operation of the Leyden phial, the operation of the electrophorus, and the dissipation of electricity by sharp points and by imperfect conductors.

The observations of Mr Watson on the necessity of connecting the rubber of an electrical machine with the ground, might have suggested to philosophers the doctrine of *plus* and *minus* electricity, especially after the valuable discoveries of Mr Symmer and Cigna. A ferocious consideration of these general facts would have led to the theory of coated glass almost at its first appearance. But the historical fact was otherwise; and a considerable time elapsed between the first experiments with charged glass by Kleit, and the clear and satisfactory account given by Dr Franklin, of all the essential parts of the apparatus, and the probable procedure of nature in the phenomenon. The impermeability of glass by the electric fluid, and the consequent abstraction of it from the one side while it was accumulated on the other, suggested to his acute mind the leading principle of electrical philosophy; namely, that all the phenomena arise from the redundancy or deficiency of electric fluid, and that a certain quantity of it resides naturally in all bodies in a state of uniform distribution, and, in this state, produces no sensible effect. This was, in his hands, the inlet to the whole science; and the greatest part of what has been since added is a more distinct explanation how the redundancy or deficiency of electric fluid produces the observed phenomena. Dr Franklin deduced this leading principle from observing, that as fast as one side of a glass plate was electrified positively, the other side appeared negative, and that, unless the electricity of that side was communicated to other bodies, the other side could be no farther electrified. Having formed this opinion, the old observations of Watson, Symmer, and Cigna, were explained at once, and the explanation of the Leyden phial would have come in course. It is for these reasons, as much as for the important discovery of the sameness of electricity and of thunder, that Dr Franklin stands so high in the rank of philosophers, and is justly considered as the author of this department of natural science. Whatever credit may be due to the chemical speculations of De Luc, Willeke, Winkler, and many others, who have attempted to associate electricity with other operations of nature, by resolving the electric fluid into its constituent parts, all their explanations presuppose a mathematical and mechanical doctrine concerning the mode of action of the ingredients, which will either account for the total inactivity of the compound, or which will explain, in the very same manner, the action of the compound itself: yet all seem

146
Of the Ley-
den phial.

to content themselves with a vague and indistinct notion of this preliminary step, and have allowed themselves to speak of electrical atmospheres, and spheres of activity, and such other creatures of the mind, without once taking the trouble of considering whether those assumptions afforded any real explanation. How different was Newton's conduct. When he discovered that the planets attracted each other in the inverse duplicate ratio of the distances, and that terrestrial gravity was an instance of the same force, and that *therefore* the deflection of the earth was the effect of the accumulated weight of all its parts; he did not rashly affirm this of the planets, till he examined what would be the effect of the accumulated attraction in the abovementioned proportion.

147. Mr Æpinus has the honour of first treading in the steps of our illustrious countryman; and he has done it with singular success in the explanation of the phenomena of attraction and repulsion, as we have already seen. In no part of the study has his success been so conspicuous as in the explanation of the curious and important phenomena of the Leyden phial. It only remained for him to account for the accumulation of such a prodigious quantity of this agent as was competent to the production of effects which seemed to exceed the similar effects in other cases, out of all proportion. Indeed, the disproportion is so great, as to make them appear to be of a different and incomparable nature. Dr Wilson's experiments in the pauthleon are therefore precious, by shewing that nothing was wanted for the production of all the effects of the Leyden phial but a surface sufficiently extensive for containing a vast quantity of fluid, and so perfectly conducting as to admit of its simultaneous and rapid transference. Therefore we assert that one of the chief merits of Mr Æpinus's theory is the satisfactory explanation of the accumulation of this vast quantity of fluid in a small space. We trust, therefore, that our readers will peruse it with pleasure. But we must here observe, that Mr Æpinus has not expressly done this in his work which we have already made so much use of, nor in any other that we know of. He has gone no farther than to point out to the mathematicians, that his hypothesis is adequate to the accounting for any degree of accumulation whatever. This he does in that part of his work which contains the formulæ of n^o 38, 39, 40, 41, &c. And he afterwards shews, that all the phenomena of attraction and repulsion which are observed in the charged jar are precisely such as are necessary consequences of his theory.

148
Theory of
charged
glasses com-
pleted by
Mr Cavendish.

It is to the Hon. Mr Cavendish that we are indebted for the satisfactory, the complete (and we may call it *the popular*), explanation of all the phenomena. Forming to himself the same notion of the mechanical properties of the electric fluid with Mr Æpinus, he examined, with the patience, and much of the address, of a Newton, the action of such a fluid on the fluid around it, and the sensible effects on the bodies in which it resided; the disposition of it in a considerable variety of cases; and particularly its action on the fluid contained in slender canals and in parallel plates;—till he arrived at a situation of things similar to the Leyden phial. And he then pointed out the precise degree of accumulation that was attainable, on different suppositions concerning the law of electric action in general.

We have given an abstract of this investigation accommodated to the inverse duplicate ratio of the distances.

From this it appears (n^o 135), that whatever quantity of electric fluid we can put into a circular plate 12 inches in diameter, by simple communication with the prime conductor of an electrical machine, we can accumulate 60 times as much in it by bringing the plate within $\frac{1}{8}$ th of an inch of another equal plate which communicates with the ground; and it appears in n^o 139, that all this accumulated fluid may be transferred in an instant to the other plate (which is shewn to be almost equally deprived of fluid), by connecting the two plates by a small wire.

But as it was also shewn in that paragraph, that the force with which the accumulated fluid was attracted by the redundant matter in the other plate was exceedingly great, and consequently its tendency to escape was proportionably increased; this accumulation cannot be obtained unless we can prevent this spontaneous transference.

150
Inexplicable by material atmospheres.

Here the non-conducting power of idio-electrics, without any diminution, the action of the electric fluid on fluid or matter on the other side of them, comes to our aid, and we at once think of interposing a plate of glass, or wax, or resin, or any other electric, between our conducting plates. Such is the immediate suggestion of a person's mind who entertains the Æpinian notion of the electric fluid; and such, we are convinced, is the thought of all who imagine that they understand the phenomena of the Leyden phial. But those who attempt to explain electric action by means of what they call electric atmosphere of variable density or intensity, are not intitled to make any such inference, nor to expect any such phenomena as the Leyden phial exhibits. Electricity, they say, acts by the intervention of atmospheres: Therefore, whatever allows the propagation of this action (conceive it in any manner whatever), allows the propagation of these agents; and whatever does not conduct electric action, does not conduct the agents. Interposed glass should therefore prevent all action on the other plate. This is true, even although it were possible (which we think it is not) to form a clear notion of the free passage of this material atmosphere in an instant, and this without any diminution of its quantity, and consequently of its action, by the displacement of so much of it by the solid matter of the body which it penetrates. Yet without this undiminished action of the electrified plate on the fluid, and on the matter, beyond the glass, and on the canal by which its fluid may be driven off into the general mass—no such accumulation can take place; and if the phenomena of the Leyden phial are agreeable to the results of the Æpinian hypothesis, all explanation by atmospheres must be abandoned. Indeed when the partisans of the atmospheres attempt to explain their conceptions of them, they do not appear to differ from what are called *spheres of activity* (a phrase first used by Dr Gilbert of Colchester, in his celebrated work *De Magnete et Corporibus Magneticis*): and spheres of activity will be found nothing more than a figurative expression of some indistinct conception of *action in every direction*. When we use the words *attraction* and *repulsion*, we do not speak a whit more figuratively than when we use the general word *action*. These terms are all figurative, only *attraction* and *repulsion* have the advantage.

vantage of specifying the *direction* in which we conceive the *action* to be exerted.

It therefore becomes still more interesting to the philosopher to compare the phenomena of CHARGED GLASS with the *Æpinian* theory. They afford an *experimentum crucis* in the question about electric atmospheres.

151
Phenomena of charged glass explained.

Let G (fig. 28.) represent the end of a prime conductor, furnished with Henley's electrometer. Let AB represent a round plate of tinfoil, pasted on a pane of glass which exceeds the tinfoil about two inches all round. The pane is fixed in a wooden foot, that it may stand upright, and be shifted to any distance from the conductor DF represents another plate of the same dimensions as AB, in the centre of which is a wire EN, having a small ball on the end N, to which is attached a Canton's electrometer. This wire passes through the wooden ball O, fastened to the insulating stand P. The glass pane must be very clean, dry, and warm. Connect the conductor G with AB by a wire reaching to the centre C. Turn the cylinder of the electrical machine slowly, till the electrometer rise to 30° or 40° , and note the number of turns. Take off the electricity; and having taken away the connecting wire GC, turn the machine again till the electrometer rise to the same height. The difference in the number of turns will give some notion of the expenditure of fluid necessary for electrifying the plate of tinfoil alone. This will be found to be very trifling when the electricity is in so moderate a degree. It is proper, however, to keep to this moderate degree of electrification, because when it is much higher, the dissipation from the edges of the plate is very great. Replace the wire, and again raise the electrometer to 30° . Now bring forward the plate DF, keeping it duly opposite and parallel to AB, and taking care not to touch it. It will produce no sensible change on the position of the electrometer till it come within four or three inches of the glass pane; and even when we bring it much nearer (if a spark do not fly from the glass pane to DF), the electrometer HG will sink but two or three degrees, and the electrometer at N will be little affected. Now remove the plate DF again to the distance of two or three feet, and attach to its ball N a bit of chain, or silver or gold thread, which will trail on the table. Again, raise the electrometer to 30° , and bring DF gradually forward to AB. The electrometer HG will gradually fall down, but will rise to its former height, if DF be withdrawn to its first situation. It is scarcely necessary to shew the conformity of this to the theory contained in n^o 134, 135, &c. As the plate DF approaches, the redundant fluid in AB acts on the fluid in DF, and drives it to the remote end of the wire EN, as was shewn by the divergency of the balls at N; and then an accumulation begins in AB, and the electrometer HG falls in the same manner as if part of the fluid in the prime conductor were communicated to AB. When DF communicates with the ground, the electrometer at N cannot shew any electricity, but much more fluid is now driven out of DF, in proportion as it is brought nearer to AB. Instead of connecting AB immediately with the prime conductor, let the wire GC have a plate at the end G, of the same dimensions as AB, having an electrometer attached to the side next to AB. Let this apparatus of two plates be electrified anyhow, and note the divergency of the electrometer at H, be-

fore DF, communicating with the ground, is brought near it, and then attend to the changes. We shall find the divergency of this electrometer correspond with the distance of DF very nearly as the theory requires.

While the plates AB and DF are near each other, State of the especially when DF communicates with the ground, if coatings. we hang a pith-ball between them by a silk thread, it will be strongly attracted by the plate which is nearest to it, whether DF or AB; and having touched it, it will be briskly repelled, and attracted by the glass pane, which will repel it after contact, to be again attracted and repelled by DF; and thus bandied between the plates till all electricity disappear in both, the electrometer attached to H descending gradually all the while.

As all these phenomena are more remarkable in proportion as the plates are brought nearer, they are most of all when DF is applied close to the glass pane. And if, in this situation, we take any accurate method for measuring the intensity of the electricity in the plate HG, before the approach of DF, we shall find the diminution, occasioned by its coming into full contact with the pane, considerably greater than what is pointed out in n^o 135. When we employed plates of 12 inches diameter, pasted on a pane one fortieth of an inch in thickness, we found the diminution not less than 199 parts of 200; and we found that it required at least 200 times the revolution of the cylinder to raise the electrometer to the same height as before. This comparison is not susceptible of great accuracy, by reason of many circumstances, which will occur to an electrician. But in all the trials we have made, we are certain that the accumulation greatly exceeded that pointed out by the *Æpinian* theory as improved by Mr Cavendish. And we must here observe, that we found this superiority more remarkable in some kinds of glass than others, and more remarkable in some other idioelectrics. We think that, in general, it was most remarkable in the coarse kinds of glass, provided they were uniformly transparent. We found it most remarkable in some common glass which had exfoliated greatly by the weather; but we also found that such glasses were very apt to be burst by the charge. The hardest and best London crown-glass seemed to accumulate less than any other; and a coloured glass, which when viewed by reflection seemed quite opaque, but appeared brown by transmitted light, admitted an accumulation *greatly* exceeding all that we have tried; but it could not be charged much higher without the certainty of being burst. This diversity in the accumulation, which may be made in different kinds of glass, hinders us from comparing the *absolute* accumulations assigned by the theory with those which experiment gives us. But though we cannot make this comparison, we can make others which are equally satisfactory. We can discover what proportion there is between the accumulation in glass of the same kind, as it may differ in thickness and in extent of surface. Using mirror glass, which is of uniform and measurable thickness, and very flat plates, which come into accurate or equable contact—we found that the accumulation is inversely as the thickness of the plates; but with this exception, that when two plates were used instead of a plate of double thickness, the diminution by the increase of thickness was not nearly in the proportion of this increase. In-

stead of being reduced to one half, it was more than two-thirds; and in the kind called Dutch plate, the diminution was inconsiderable.

The experiments with the Dutch and other double plates, suggested another instructive and pretty experiment. Observing these plates to cohere with considerable force, it was thought worth while to measure it; which was attempted in this manner: Two very flat brass plates AB, DF (fig. 29.) furnished with wires and balls, were suspended, about three inches asunder, by silk threads, as represented in the figure. At G was attached a very fine silver wire, which hung very loose between it and the prime conductor, without coming near the table. Another was attached to N, which touched the table. A plate of mirror glass was set between them, as shewn by QR. When this apparatus was electrified, the threads of suspension immediately began to deviate from the perpendicular, and the plates to approach the glass pane and each other. The pane was carefully shifted, so as to be kept in the exact middle between them. This result shewed very plainly the pressure of the fluid on one of the plates, and the mutual attraction of the redundant matter and redundant fluid. This increased as the accumulation increased; and it was attempted to compare the attraction with the accumulation, by comparing the deviation of the suspending threads with that of the electrometer attached to the prime conductor; but we could not reconcile the series (which, however, was extremely regular) with the law of electric action. This harmony was probably disturbed by the force employed in raising the silver wires. When more flexible silver threads were used, much was lost by dissipation from the roughness of the thread. We did not think of employing a fine flaxen thread moistened: but, indeed, an agreement was hardly to be expected; because theory teaches us, that the distribution of the redundant fluid in AB will be extremely different from the distribution of the redundant matter in DF, till the plates come very near each other. The accumulation in AB depends greatly on the law of distribution, being less (with any degree of redundancy) when the fluid is denser near the centre of the plate. Other circumstances concurred to disturb this trial; but the theory was abundantly confirmed by the experiment, which shewed the strong attraction arising from the accumulation. This was so great, that although the plates were only three inches in diameter, and the glass pane was $\frac{1}{2}$ of an inch thick, and the threads deviated about 18 degrees from the perpendicular—it required above an ounce weight, hung on the wire EN, to separate the plates from the glass.

The experienced electrician need not be told, that by bringing the two ends of a bent wire in contact with the two plates (first touching DF with it) discharges the apparatus, and causes the plates to drop off from the pane. But he may farther observe, that if there be attached to each end of the discharging wire a downy feather, and if he first bring the end near the plate DF, and observe the feather to be not at all, or but a very little, affected, and if he then bend round the other end toward the plate AB, both feathers will immediately stretch out their fibres to the plates, and cling fast to them, long before the discharging spark is seen. This is a fine proof of the process of discharge, which begins by the induction of electricity on the ends of the

discharging wire; first, negative electricity on the end that approaches A, and, in the same instant, opposite electricities at D and the adjoining end of the wire.

The following observation of Professor Richmann of St Peterburgh (the gentleman who fell a sacrifice to electrical studies by a thunder stroke from his apparatus) is extremely instructive and amusing. Let a glass pane be coated on both sides, and furnished with a small electrometer attached to the coatings. It is represented as if seen edgewise in fig. 30. Let it be charged positively (that is, by redundancy) by the coating AB, while DF communicates with the ground. The electrometer A *a* will stand out from the plate, and D *d* will hang down close by its coating, as long as DF communicates with the ground. But as the electricity gradually dissipates by communication to the contiguous air, the ball *a* will gradually, but very slowly, fall down. We may judge of the intensity of the remaining electricity by the deviation of the electrometer, and we may conceive this deviation divided into degrees, indicating not angles, but intensities, which we conceive as proportional to the redundancy or deficiency which occasion them.

If we take away the communication with the ground, we shall observe the ball *a* fall down very speedily, and then more slowly, till it reach about half of its first elevation. The ball *d* will at the same time rise to nearly the same height; the angle between the two electrometers continuing nearly the same as at first. When *d* has ceased to rise, both balls will very slowly descend, till the charge is lost by dissipation. If we touch DF during this descent, *d* will immediately fall down, and *a* will as suddenly rise nearly as much; the angle between the electrometers continuing nearly the same. Remove the finger from DF, and *a* will fall, and *d* will rise, to nearly their former places; and the slow descent of both will again continue. The same thing will happen if we touch AB; *a* will fall down close to the plate, and *d* will rise, &c. And this alternate touching of the coatings may be repeated some hundreds of times before the plate be discharged. If we suspend a crooked wire *v m u*, having two pith balls *v* and *u* from an insulated point *m* above the plate, it will vibrate with great rapidity, the balls striking the coatings alternately; and thus restoring the equilibrium by steps. Each stroke is accompanied by a spark.

All these phenomena are not only consequences of the theory, but their measures agree precisely with the computations deduced from the formulæ in n^o 22, 23, 24, accommodated to the case by means of n^o 135 and 136, as we have verified by repeated trials. But it would occupy much room to trace the agreement here, and would fatigue such readers as are not familiarly conversant with fluxionary calculations. The inquisitive reader will get full conviction by perusing Epinus's Essay, Appendix i. A very distinct notion may be conceived of the whole process, by supposing that in a minute AB loses $\frac{1}{10}$ th of the unbalanced redundancy actually in it, and consequently diminishes as much in its action. It will be proved afterwards, that the dissipations in equal times are really in proportion to the superficial repulsions then exerted. We may also suppose, that the action of the redundant fluid, or redundant matter, in either coating, on the external fluid contiguous to it, is to its action on the fluid contiguous to

154
Strong attraction between them.

156
Beautiful and instructive experiment by Professor Richmann.

155
Discharge; how it is effected.

the other coating in the constant proportion of 10 to 9. We select this proportion for the simplicity of the computation. Then the difference of these actions is always $\frac{1}{10}$ th of the full action on the fluid contiguous to it. This is also an exact supposition in some particular case, depending on the breadth of the coating and the thickness of the pane.

Now, let the primitive unbalanced repulsion between AB and the contiguous fluid of the electrometer be 100, while DF communicates with the ground. The ball *a* will stand at 100; the ball *d* will hang touching DF. Then *a*, by losing $\frac{1}{10}$ th, retains only 90, and would sink to 90°. But as this destroys the equilibrium on the other side, fluid will enter into DF, so as to reduce the deficiency $\frac{1}{10}$ th. Therefore nine degrees of fluid will enter; and its action on *a* will be the same as if $\frac{9}{10}$ ths of 9, or 8,1 had been restored to AB. Therefore *a* will rise from 90 to 98,1; or it will sink in one minute from 100 to 98,1.

But if we have cut off the communication of DF with the ground, this quantity of fluid cannot come into DF; and the quantity which really comes into it from the air will be to that which escapes from A as the attraction on the side of DF, to the repulsion on the side of AB. By the diminution of the repulsion $\frac{1}{10}$ th, and the want of 9 degrees of fluid in DF to balance it, DF acquires an attraction for fluid which may be called 9. Therefore, since $\frac{1}{10}$ th of the primitive repulsion of AB has dissipated 10 measures of fluid in the minute, the attraction of DF will cause it to acquire $\frac{1}{10}$ th of 9, or 0,9, from the air in the same minute. At the end of the minute, therefore, there remains an unbalanced attraction for fluid = 8,1; and consequently an unbalanced repulsion between the redundant matter in DF, and that in the ball *d*. Therefore *d* will rise to 8,1. But *a* cannot now be at 98,1; because DF has not acquired 9 measures of fluid, but only $\frac{9}{10}$ ths of one measure. Therefore *a*, instead of rising from 90 to 98,1, will only rise to $90 + \frac{9}{10}$ ths $\times \frac{9}{10}$ ths; that is, to 90,81.

At the close of the minute, therefore, *a* is at 90,81, and *d* is at 8,1, and their distance is 98,91. In the next minute, AB will lose $\frac{1}{10}$ th of the remaining unbalanced electricity of that side, and DF will now acquire a greater proportion than before; because its former unbalanced attraction gets an addition equal to $\frac{9}{10}$ ths of the loss of AB. This will make a larger compensation in the action on *a*, and *a* will not fall so much as before. And because in the succeeding minutes the attraction of DF for fluid is increasing, and the repulsion of AB is diminishing, the compensation in the action on *a*, by the increased attraction of DF, continues to increase, and the descent of *a* grows continually slower; consequently a time must come, when the repulsion of AB for fluid is to the attraction of DF for it, nearly in the proportion of 10 to 9. When this state obtains, *d* will rise no more; because the receipt of fluid by DF, being now $\frac{9}{10}$ ths of the loss by AB, it will exactly compensate the additional attraction of DF for fluid, occasioned by that loss. The next loss by AB not being so great, and the next receipt by DF continuing the same, by reason of its undiminished attraction, there will be a greater compensation in the action on *a*, which will prevent its descending so fast; and there will be more than a compensation for the ad-

ditional attraction of DF for fluid: that is, the fluid which has now come into DF will render it, and also the ball *d*, less negative than before; and therefore they will not repel so strongly. Therefore *d* must now descend. It is evident, that similar reasons will still subsist for the slow descent of *a*, and the slower descent of *d*, till all redundancy and deficiency are at an end.

This maximum of the elevation of *d* happens when *a* has descended about one half of its elevation; that is, when the unbalanced repulsion of AB is reduced to about one-half. For if one-half of the unbalanced fluid be really taken out of AB, and if DF can get no supply whatever, it must acquire an attraction corresponding to $\frac{9}{10}$ ths of this; and if the supply by the air be now opened to it, things will go on in the way already described, till all is discharged.

This account of the process is only an approximation; because we have supposed the changes to happen in a desultory manner, as in the popular way of explaining the acceleration of gravity. The rise of *d* is not at an end till the attraction of DF for fluid is to the repulsion of AB as 19 to 20.

But if we interrupt this progress in any period of it, by touching DF, we immediately render it neutral, and *d* falls quite down, in consequence of receiving a complete supply of fluid. But this must change the state of AB, and cause it to rise $\frac{9}{10}$ ths of the descent of *d*. As *a* and *d* were nearly at an equal height before DF was touched, it is plain that *a* will rise to nearly twice its present height; after which, the same series of phenomena will be repeated as soon as the finger is removed from DF.

If, instead of touching DF, we touch AB, the same things must happen; *a* must fall down, and *d* must rise to nearly twice its present height, and all will go on as before, after removing the finger. Lastly, if instead of allowing either side to touch the ground alternately, we only touch it with a *small insulated body*, such as the wire with the balls *v* and *u*, the ball attached to the side touched sinks, till the electricity is shared between the coating and the wire with balls. The ball attached to the other coating rises $\frac{9}{10}$ ths of the sinking of the first ball. The crooked wire ball is now repelled by the coating which it touched, and the other ball is brought near to the other coating, and must be attracted by it, because the electricities are opposite. This operation evidently tends to transfer the redundant fluid *by degrees* to the side where it is deficient. It needs no explanation. We shall only mention a thing which we have always observed, without being able to account for it. The vibration of the wire acquires a certain rapidity, which continues for a long while, and suddenly accelerates greatly, and immediately afterwards ceases altogether.

This pretty experiment of Professor Richmann will be found very instructive; and will enable us to understand the operation of the electrophorus, and to see the great mistake of those who say that it is perfectly similar to a discharged glass plate.

Thus, then, we see, that all the classes of phenomena, connected with attraction and repulsion, are precisely such as would result from the action of a fluid so constituted. The complete undiminished action of the cause of those phenomena on the other side of the interposed non-conductor of that cause is demonstrated, and all

all explanation by the mechanical action of material elastic atmospheres of variable density must be abandoned, and the infinitely simpler explanation by the attractive and repulsive forces of the fluid itself must be preferred.

So happily does the Franklinian theory of positive and negative electricity explain the phenomena, when a suitable notion is formed of the manner of action of this fluid. We cannot but think that this is attained, when, to the general doctrine of Æpinus, we add the specification of the law of action, so fully verified by the experiments of Mr Coulomb, which are in the hands of the public, and are of that simple nature that any careful experimenter can convince himself of their accuracy (Sec n^o 144.) We may therefore proceed with some confidence, and apply this doctrine even to cases where experiment does not offer itself for proof.

Dr Franklin affirms that electric fluid cannot be thrown into one side of the coated pane unless it be abstracted from the other; and that therefore the charged glass contains no more than it did before charging. We indeed find that we cannot charge the inside, if the outside do not communicate with the ground. He proves it also by saying, that if a person, when insulated, discharges a glass through his own body, he is not found electrified: And he infers, as a necessary consequence of this, that a series of any number of jars may be charged by the same turns of a machine, if we make the outside of the first communicate with the inside of the second, and the outside of the second with the inside of the third; and so on; and the outside of the last communicate with the ground. Having made the trial, and having found that more turns of the machine were necessary, he attributes this to dissipation into the air by the communication. But our theory teaches us otherwise. We learn from it, that the redundant matter in the plate DF is less than the redundant fluid in AB, in the proportion of $n - 1$ to n ; and therefore the redundant fluid in the overcharged side of the next plate is no greater. The charge or redundancy in the

m th jar of the series will therefore be $\frac{n-1}{n}m$. Thus,

if n , or the charge of the first jar, be 60, the charge of the 10th jar will be nearly 51. Although a coated plate cannot be charged unless one of the coatings communicate with the ground, it may be electrified as much as one of the coatings can be alone. And this is seen in our attempt to charge it: For as soon as we attempt to electrify one side, the other is electrified also; for it gives a spark which no unelectrified body will do. Also, when we discharge a jar by an insulated discharger, we always leave it electrical in the same way with the body from which it was charged. If a man is not found electrified after having discharged a jar through his own body, it is owing to the great surface of his body, which reduces the simple electrification of a side of the jar to a very insignificant and insensible quantity.

Wilcke (and we believe Franklin before him) maintains, that when the jar has been charged, by connecting one side with the prime conductor, and the other with the rubber, it is neutral and inactive on both sides. But this is not so; and a slight reflection might have convinced them that it cannot be so: if it were, the jar could not be discharged. Each side, while con-

nected with the machine, must be in the condition of the part with which it is connected, and in a disposition to take or give. If the trial be carefully made, it will be found to be equally active on both sides; and the discharging rod, having down on its ends, will shew this in an unequivocal manner, and shew that its condition differs in this respect from that of a jar charged in the ordinary way. It is in the maximum state of Richmann's plate, described in n^o 156. when d rises no more.

In discharging a jar A, if instead of the outside communicating with the inside by a wire, we make it communicate with the inside of a second jar B, while the outside of B is made to communicate with the inside of A, we shall find be charged by the discharge of A; and that the discharge of A is not complete, the charge 2^2 always remaining, whatever may have been the magnitude of n .

We may infer from this experiment, that when shock is given to a number of persons $a, b, c,$ &c. we are not to conclude, that the fluid which comes out the deficient side of the jar is the same which came out of the redundant side. The whole, or perhaps only a part, of the moveable fluid in the person a goes into b , replacing as much as has passed from b into $c,$ &c. Indeed, where the canal is a slender wire, we may grant that great part of the individual particles of fluid which were accumulated on the inside of the jar have gone into the outside. Perhaps the quantity transferred, even in what we call a very great discharge, may be but a small proportion of what naturally belongs to a body. This may be the reason why a charge will not melt more than a certain length of wire. Mr Cavendish ascribes this to the greater obstruction in a longer wire; but this does not appear so probable. A greater obstruction would occasion a longer delay of the transference; and therefore the action of the same quantity would be longer continued. He proves, that a metal wire conducts many hundred times faster than water; yet, when water is dissipated by a discharge, it is found to have actually conducted a much greater proportion of the whole charge. We ascribe it chiefly to this, that, in a short wire, the quantity transferred exceeds the whole quantity belonging to the wire.

It is surely needless to prove that the theory of the Leyden phial is the same with that of the coated pane. The only difference is, that we are not so able to tell the disposition of the accumulated fluid, and the evacuated matter, in every figure. When the phial is of a globular form, and of uniform thickness, with an exceedingly small neck, we then knew the disposition more accurately than in a plate. The redundant fluid is then uniformly distributed. If we could insure the uniformity of thickness, such a phial would be an excellent UNIT for measuring all other charges by; but we can neither insure this (by the manner of working glass), nor measure its want of uniformity: whereas we can have mirror plate made of precisely equal thickness, and measure it. This, therefore must be taken as our unit.

And here we remark, that this gives us the most perfect of all methods for comparing our theory with experiment. We must take two plates, of the same glass and the same thickness, but of different dimensions of coated surface. We must charge both by very long conducting wires on both sides, and then measure

158 Franklin mistaken in supposing that a charged plate contains its natural quantity of fluid.

159 Mistake of Wilcke's.

160 Charge one jar by the discharge of another.

161 Important inference.

162 Leyden phial like a coated pane.

163 Excellent method for verifying the theory.

how often the charge of the one is contained in the other. Mr Cavendish has given an unexceptionable method of doing this independent of all theory. As it applies equally to jars, however irregular, we shall take it altogether.

Measure of a charge. When a jar is charged, observe the electrometer connected with it, and immediately communicate the charge to another equal jar (the perfect equality being previously ascertained by the methods, which will appear immediately). Again note the electrometer. This will give the elevation, which indicates one-half, independent of all theory. Now electrify a jar, or a row of equal jars, to the same degree with the first, and communicate the charge to a coated mirror plate, discharging the plate after each communication, till the electrometer reaches the degree which indicates one-half. This shews how often the charge of the plate is contained in that of the jar or row of jars.

Let the charge of the plate be to that of the jars as x to 1. Then, by each communication, the electricity is diminished in the proportion of $1 + x$ to 1. If m communications have been made, it will be reduced in the proportion of $1 + x^m$ to 1. Therefore $1 + x^m = 2$, and $1 + x = \sqrt[m]{2}$, and $x = \sqrt[m]{2} - 1$.

When x is small in proportion to 1, we shall be very near the truth, by multiplying the number of communications by 1,444, and subtracting 0,5 from the product. The remainder shews how often the charge of the plate is contained in that of the jars, or $\frac{1}{x}$.

Thus may the perfect equality of two jars be ascertained; and the one which exceeds, on trial, may be reduced to equality by cutting off a little of the coating. An electrician should have a pair of small jars or phials so adjusted. It will serve to discover in a minute or two the mark of one-half electricity for any electrometer, and for any degree; as also for measuring jars, batteries, shocks, &c. much more accurately than any other method: because such phials, constructed as we shall describe immediately, may be made so neutral, and so retentive, that the quantity which dissipates during the handling becomes quite insignificant in proportion to the quantity remaining; whereas, in all experiments with electrometers, constructed with the most curious attention, the dissipations are great in proportion to the whole, and are capricious.

164. It was chiefly by this method that the writer of this article, having read Mr Cavendish's paper, compared the measures given by experiment with those which result from an action in the inverse duplicate ratio of the distance. When the charges were moderate, the coincidence was perfect; when the charges were great, the large plates contained a little more. This is plainly owing to their being less disposed to dissipate from the edges.

165. Maxims for constructing jars, batteries, &c. We may now follow with some confidence the practical maxims deducible from the theory for the construction of this accumulating apparatus. The theory prescribes a very conducting coating, in close and uninterrupted contact: It prescribes an extensive surface, and a thin plate of idio-electric substance. Accordingly all these are in fact attended by a more powerful effect. Metal is found to be far preferable to water, which was first employed, having been suggested by the

original experiments of Gray, Kleist, and Cunaus. A continuous plating is prescribed, in preference to some methods commonly practised; such as filling the jar with brads dust, or gold leaf, or covering its surface with filings stuck on with gum water, or coating the inside with an amalgam of mercury and tin. This last appears, by reflection from the outside, to give a very continuous coating; but if we hold the jar between the eye and the light, we may perceive that it is only like the covering with a cobweb. Yet there are cases where these imperfect coatings only are practicable, and some rare ones where they are preferable. In the Hint for medical exhibition of electricity, where the purpose intended is supposed to require the transfusion of a great quantity of the electric fluid, any thing that can diminish the irritating smartness of the spark is desirable. This is greatly effected by those imperfect coatings. Small shocks, which convey the same quantity of fluid with the sharp pungent and alarming spark from a large surface, are quite soft and inoffensive, greatly resembling the spasmodic quivering, sometimes felt in the lip or eye-lid, and will not alarm the most fearful patient.

166. Close contact of the metallic coating is observed to increase the effect of the charge. But it is also found that it greatly increases the risk of bursting the glass by spontaneous discharge through its substance. An experienced electrician (we think it is Mr Brookes of Norwich) says, that since he has employed paper covered with tinfoil, with the paper next the glass, instead of the foil itself, he has never had a jar burst; whereas the accident had been very frequent before. The theory justifies this observation. Paper is an imperfect conductor, even when soaked with flour paste; and the transfusion, though rapid, is not instantaneous nor defultory, but begins faintly, and swells to a maximum. It operates on the glass, like gradual warming, instead of the sudden application of great heat.

167. Mr Cuthbertson, an excellent artist in all electrical apparatus, and inventor of the best air-pump, has made a very curious observation on this subject. He says that he has uniformly observed, that jars take a much greater charge (nearly one-third), if the inside be considerably damped, by blowing into it with a tube reaching to the bottom (*Nicholson's Journal*, March 1799).—We must acknowledge, that we can form no distinct conception of what Mr Cuthbertson calls an undulation of the elastic atmosphere. We do not know whether he means that the atmosphere is actually undulating as water, or as air in the production of sound, as its parts being in a reciprocating motion; or whether he only means that this atmosphere consists of quiescent strata, alternately denser and rarer. Nor can we form any notion how either of these undulations contributes to the explosion, or prevents it. We are really but very imperfectly acquainted with that part of the science which should determine the precise accumulation that produces the defultory transference. We mentioned one necessary consequence of the action inversely as the square of the distance, which has some relation to this question, viz. that a particle, making part of a spherical surface, is twice as much repelled when it has just quitted the surface, as when it made part of it, provided its place be immediately supplied. And another circumstance has been frequently mentioned, viz. that a greater, and perhaps much greater, force is necessary for enabling a particle

Hint for medical exhibition of electricity.

How to prevent the bursting of jars by high charges.

Very curious observation by Mr Cuthbertson.

particle of fluid to quit the last series of particles of the solid matter than for producing almost any constipation. But we are not certain that these circumstances are of sufficient influence to explain the whole of the event. *Valeant quantum valere possunt.* Yet we are of opinion that Mr Cuthbertson has assigned the true cause, namely, the imperfect coating of the inside of the glass. When we come to the explanation of the escape of electricity along imperfect conductors, we hope that it will appear, that the disposition to escape must be greatly diminished by a charge, which disposes the fluid so, that in no place the constipation is remarkably greater than in another part very near it, and the density changes everywhere slowly.

¹⁶⁸
Best forms
for jars, &c. With respect to the form of the coated glass, the theory prescribes that which will occasion such a distribution of the electric fluid as shall make its repulsion for the fluid in the canal which connects it with the prime conductor as little as possible. In this respect it would seem that a plate is the best, and a globe the worst: but if both are very thin, the difference cannot be considerable. Our experience, however, seems to indicate the opposite maxim as the most proper. We have uniformly found a globe to be far preferable to a plate of the same thickness, and that a plate was generally the weakest form. It must be owned that we have not yet been able to ascertain by the theory what is the exact distribution of the redundant fluid in a plate. In a sphere it must be uniformly spread over the surface. We must also ascribe part of the inferiority of the plate to its greater tendency to dissipation from the edges. If a plate be coated in a star-like form, with slender projecting points, we shall observe them luminous in the dark, almost at the beginning of the accumulation; and the plate will discharge itself by these points, over the uncoated part, before it has attained any considerable strength. Those forms are least exposed to this deterioration which have the least circumference to the same quantity of surface. We have always found that a square coating will not receive a more powerful charge without exploding than a circular one of the same breadth, although it contains a fourth more surface; and this although any visible escape from the angles be prevented by covering the outline with sealing wax. Of all forms, therefore, a globe, with a very narrow, but long neck, is the most retentive. But it is very difficult to coat the inside of such a vessel. The balloons used in chemical distillations make excellent jars, and can be easily coated internally when the neck will admit the hand. The thinnest of tinfoil may be used, by first pasting it on paper, and then applying it either with the foil or the paper next the glass. It should be cut into gussets, as in the covering of terrestrial globes; and they should be put on overlapping about half an inch. The middle of the bottom is then coated with a circular piece. The great bottles for holding the mineral acids are also good jars, but inferior to the balloons, because they are very thick in the bottom, and for some distance from it. A box of balloons contains more effective surface than an equal box of jars of the same diameter and height of coating.

¹⁶⁹
Compendious battery. The most compendious battery may be made in the following manner: Choose some very flat and thin panes of the best crown glass, coat a circle (*abcd*), (fig. 31.) in the middle of both surfaces, so as to leave

a sufficient border uncoated for preventing a spontaneous discharge; let each of them have a narrow slip of tinfoil *a* reaching from the coating to the edge on one side, and a similar slip *c* leading to the opposite edge on the other side. Lay them on each other, so that the slips of two adjoining plates may coincide. Connect all the ends of these slips on one side together by a slip of the same foil, or a wire which touches them all. Then, connecting one of these collecting slips with the prime conductor, and the other with the ground, we may charge and discharge the whole together. If the panes be round, or exact squares, we may employ as few of them together as we please, by setting the whole in an open frame, like an old-fashioned plate-warmer; and then turning the set which we would employ together at right angles to the rest. This evidently detaches the two parcels from each other. This battery may be varied in many ways; and if the whole is always to be employed together, we may make it extremely retentive, by covering the uncoated border of the plate with melted pitch, and, while it is soft, pressing down its neighbour on it till the metallic coatings touch. For greater variability this may be done in parcels of the whole.

¹⁷⁰
Another. On the same principle, a most compendious battery may be made by alternate layers of tinfoil and hard varnish, or by coating plates of very clear and dry Muscovy glass. But these must be used with caution, lest they be burst by a spontaneous discharge; in which case we cannot discover where the flaw has happened. They make a surprising accumulation, without shewing any vivid electricity.

¹⁷¹
Portable. We have made a very fine electric phial for carrying about, by forming tin-plate (iron plate tinned) into jar. somewhat of a phial shape, with a long neck. We then covered this with a coating of fine sealing wax, about $\frac{1}{3}$ th of an inch thick, quite to the end of the neck, and coated the sealing wax, all but the neck, with tinfoil. It is plain that the sealing wax is the coated idio-electric, and that the tin-plate phial serves for an inner coating and wire. The dissipation is almost nothing if the neck be very small; and it only requires a little caution to avoid bursting by too high a charge. Even this may be prevented by coating the sealing wax so near to the end of the neck, that a spontaneous discharge must happen before the accumulation is too great.

¹⁷²
Importance of a close discharge. It is well known that the discharge happens when the discharging balls are at a considerable distance from each other; therefore only as much is discharged as corresponds to that distance. This is one cause of the residuum of a discharge which sometimes is pretty considerable. Some experiments require the very utmost force of the charge. It is therefore proper to make the discharge as close and abrupt as possible. But the most rapid approach that we can make of the discharger is nothing in comparison with the velocity with which the fluid seems to fly off, and will therefore have but small influence in making a more instantaneous and complete discharge. Theory points out the following method: Let a very thick plate of glass (half an inch), of several inches diameter, be put between the discharging balls, which should, in this case, be small, and let these balls be strongly pressed against it by a spring. While the charge is going on, a very small part of the glass plate, round

round the points of contact, will receive a weak and useless charge; but this will not hinder the battery from acquiring the same intensity of charge. When this is completed, let the intervening glass plate be briskly withdrawn. The discharge will begin with an intensity which is unattainable in the ordinary manner of proceeding.

173
Lateral explosion.

Much has been said of the lateral explosion. It appears, that in some of the prodigious transferences of electricity that have taken place in the discharge of great surfaces through wires barely sufficient to conduct them, flashes of light are thrown off laterally; but the most delicate electrometer, it is said, is not affected. The fact is not accurately narrated; we have always observed a very delicate electrometer to be affected. The passage of such a quantity of fluid is almost equivalent to the co-existence of it in any given section of the wire; but it remains there for so short a time, that, acting as an accelerating force, it cannot produce a very sensible motion. It is like the discharging a pistol ball through a sheet of paper hanging loosely. It goes through it without very sensibly agitating it.

174
Proposal for discovering which is redundant electricity.

It has sometimes appeared to us probable that, by means of this lateral explosion, the direction of the current may be discovered. Let the jar *ab* (fig. 32.) be discharged by a wire *acdeb*, interrupted at *cd* by the coating of a very thin plate of talc; let the coating also be very thin. There must be some obstruction to the motion, which must cause the fluid to press on the sides or surfaces of the coating, just as the obstruction to the motion of water in a pipe (arising from friction, or even from material obstacles in the pipe) causes the water to press on the sides of the pipe. Therefore if a wire *xe* connect the other coating with the ground, we should expect that fluid will be expelled along this wire, and a charge be given to the plate of talc. Now whether the course in this apparatus be from *b* to *a*, or from *a* to *b*, if any charge be acquired by *cd*, it will probably be positive in *cd*, and negative in *xe*; for it is electric fluid that is supposed to pass; therefore we should always have one species of electricity, whether *a* has been charged by glass or by sealing wax; and this species will indicate which is positive. We have said "probably"—for it is not impossible that it may be otherwise. If the abstraction at *d* be supposed more powerful than the supplying force at *c*, the same obstruction may perhaps keep the plate *cd* in an absorbing state, just as water descending in a vertical pipe, into which it is pressed by a very small head of water in the cistern, instead of pressing the sides of the pipe, rather draws them inwards, as is well known. This seems, at any rate, an interesting experiment; for we must acknowledge, that there still hangs a mysterious curtain before a theory which deduces so much from the presence of a substance which we have never been able to exhibit alone, and where we do not know when it abounds and when it is deficient. It is like the phlogiston of Stahl, or the caloric of Lavoisier. It will be proper to use the thinnest plate of talc to be charged, and to connect it with another coated plate of half the diameter, or less, in order to increase the accumulation. It seems by no means a desperate case.

The theory of coated glass now explained, might have been treated with more precision, and the formula

deduced in the beginning of this article might have been employed for stating the sum total of the acting forces, and thus demonstrating with precision the truth of the general result; and indeed it was with such a view that they were premised: but they would have been considerably complicated in the present case; for however thin we suppose the tin-foil coatings to be, it is evident from n 92, &c. that each coating will consist of three strata; of which the two outermost are active, and must have their forces stated, and the statement of the force of each stratum would have consisted of three terms. This would have been very embarrassing to some readers; and the force of the conclusion would not, after all, have been much more convincing than we hope the above more loose and popular account has been.

We have hitherto considered the non-electric coatings only, and have not attended to what may chance to obtain in the substance of the coated electric themselves. May not part, at least, of the redundant fluid be lodged in one superficial stratum of the glass? or, if it do not penetrate it, may it not adhere to the surface, and drive off from the other surface, or stratum, a part of what naturally adheres to it? Till Dr Franklin's notions on the subject became prevalent, no person doubted this. The electric was supposed to contain or to accumulate in its surface all the electricity that we know. But the first suggestion of Dr Franklin's experiments certainly was, that the electric plate or vessel acted merely as an obstacle, preventing the fluid from flying from the body where it was redundant to that where it was deficient. It is therefore an important question in the science, whether the glass or electric concerned in these phenomena serve any other purpose besides the mere prevention of the redundant fluid from flying to the negative plate?

Now it appears, at the very first, that this is the case. For if a glass be coated only on one side, and be electrified on that side, we obtain a strong spark from the other side by bringing the knuckle near it: and this may be obtained for some time from one spot of that surface; and after this we get no more from that spot, but get sparks, with the same vivacity, and in the same number, from any other spot that is opposite to the coating on the other side. In this manner we can obtain a succession of sparks from every inch of surface opposite to the coating, and from no other part. But what puts this question beyond all doubt is, that if we now lay a metal coating on the surface from which the sparks have been drawn in this manner, and make a communication between the two metallic coatings, by means of a bent wire, we obtain a perfect discharge. To complete the proof, we need only observe that this experiment succeeds whether the glass has been electrified by excited glass or by excited sealing-wax. Therefore the coated surface may receive the electric fluid by the coating, as we see plainly that it is abstracted by the coating. The use of the coatings may be nothing more than to act as conductors to every part of the surface of the electric. None of these thoughts escaped the penetrating and sagacious mind of Dr Franklin. He immediately put it to the test of experiment; and, laying a moveable metallic coating on both surfaces, he found the glass charge perfectly well. He lifted off the coatings; which operation was accompanied by flashes

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Does the charge reside in the coatings or in the glass?

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It is in the glass.

flashes of light between the metallic coverings and the glass from which he separated them. Having removed the coatings, he applied others, completed the circle, and obtained a perfect discharge, not distinguishable from what he would have obtained from the first coatings.

Thus it was demonstrated, that the glass plate itself acquired by charging a redundant stratum on one side, and a deficient stratum on the other side; and we now see, at once, the reason why the accumulation turns out greater than what is determined by the theory. The distance between the redundant and deficient stratum is less than the thickness of the glass; and this, perhaps, is an unknown proportion.

This precious experiment of Dr Franklin was repeated by every electrician, and varied in a thousand ways. No philosopher has carried this research farther than Beccaria; and he has given ground for a most important discovery in the mechanical theory, namely, that the charged glass has several strata, of inconceivable thinness, alternately redundant and deficient in electric fluid; and that by continuing the electrification, these strata penetrate deeper into the glass, and probably increase in number. We have not room here to give even an account of his experiments, and must refer the philosophical and curious reader to that part of his valuable Treatise where he treats of what he calls *vindicating or recovering electricity*; as also to a paper by Mr Henly in Phil. Transf. for 1766, giving account of experiments on Dutch plates by Mr Lane. The general form of the experiment is this. He puts two plates together; he coats the outer surfaces, and charges and discharges them as one thick plate. Their inner touching surfaces are found strongly electrical after the discharge, having opposite electricities, and changing these electricities, by repeated separations and replacings, in a way seemingly very capricious at first sight, but which the attentive reader will find to be according to fixed laws, and agreeably to the supposition that the strata gradually shift their places within the glass, very much resembling what we observe on a long glass rod which we would render electric by induction. In this case, as was observed in n° 57. there are observed more than one neutral point, &c.

Mr Cavendish endeavours to give us some notion of the disposition of the fluid in the substance of the glass in the following manner: Having separated the coated plate from the machine and from the ground, suppose a little of the redundant fluid in $B\beta\delta D$ (fig. 33.) equal to the fluid wanting in $E\epsilon\phi F$. If we now suppose all the redundant fluid to be lodged in $b\beta\delta d$, and $e\epsilon\phi f$ to hold all the redundant matter, and the two coatings to be in their natural state, a particle p , placed in the middle of the surface bd , will be nearly as much attracted by $e\epsilon\phi f$ as it is repelled by $b\beta\delta d$ (exactly so if the plates were infinitely extended); and if the coating be removed, keeping parallel and opposite to the surface that it quits, there will be very little, if any, tendency to fly from the glass to the coating: there will rather be some disposition in the fluid to quit the coating and fly to the glass; because the repulsion of $b\beta\delta d$ is more diminished than the attraction of $e\epsilon\phi f$. (n° 42.) But the difference will be very small indeed. (*N. B.* the result would be very different if electric ac-

tion followed a different law. Were it as $\frac{1}{d^3}$, the coating would be much overcharged; and were it as $\frac{1}{d}$, it would be very much undercharged). Now the fact is, that when the coating is carefully removed, it is possessed of very little electricity, not more than may reasonably be supposed to run into it by bringing away one part before another. It is impossible to keep it mathematically parallel.

Hence we may conclude that the greatest part of the redundant fluid is lodged in the glass if the plates be thin, and the redundant fluid bear but a small proportion to the natural quantity. Similar reasoning shews that the greatest part of the deficiency is in the other side of the glass; and that therefore the coatings are very nearly in their natural state, and merely serve the purpose of conducting.

We have employed coatings of considerable thickness, having holes through them, opposite to which was some gold leaf of the heaviest sort, and almost free of cracks. We have examined the state of the bottom of those pits in Mr Coulomb's manner, and always found them void of electricity.

Thus we learn that glass, and probably all other electric, acquire redundant and deficient strata as well as the most perfect conductors, at the same time that they may be impervious to the fluid; and we get some mode of conceiving how the rupture happens by a strong charge. This may very probably happen when the strata have formed, in alternate order, so deep in the glass, that a stratum, in which the fluid is crowded close together, may become contiguous to one deprived altogether of fluid. We cannot, however, say with confidence, what *should* be the effect of this state of things; or of one constricted stratum coming in contact with another.

This view of the condition of charged glass explains (we think) several phenomena which seem not well understood by electricians.

The residuum of a discharge is frequently owing to a charge extending beyond the coating, where the action is considerably irregular, or different from what it would be if the plates were infinitely extended. This *outline* charge is taken up by the coated part after a very little while, and may again be discharged. But it also frequently arises from another stratum (much thinner, as it will always be) than the exterior one, coming to the surface some time after the first discharge, and being now in a condition for being discharged. It explains the sparkling that is perceived in succession between the parts of a jar that is coated in spots, during the charge, and the very sensible residuum of the charge of such a vessel. It explains the phenomena of Beccaria's *Electricitas Vindex* (see ELECTRICITY, *Encycl.* n° 48.), and the great difference that may be found in the different kinds of glass in this respect. It explains the great difference between the sensation occasioned by a spark from a perfectly conducting surface of considerable extent, and that occasioned by a shock, which conveys the same quantity of fluid accumulated in a small surface of glass. The discharge of the first is almost instantaneous, while that of the last requires a small moment of time, and is therefore less desultory

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Charged glass acquires redundant and deficient strata.

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Conjecture about the bursting of jars.

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Several phenomena explained.

178.

and abrupt. The one is pungent and startling; but the other is softer in the first instant, and swells to a maximum. Therefore, in the medical employment of electricity, when the purpose is to be affected by the transfusion of a great quantity of electric fluid, we should recommend very small shocks from a very large surface of coated glass, very faintly electrified, in place of strong sparks. Patients of irritable constitutions are frequently alarmed by the quickness and pungency of strong sparks: but if the balls of Lane's shock-measurer be set so close as to give four or five shocks in each turn of a seven inch cylinder, the shocks are not even disagreeable. The balls should be made of fine cupelled silver: in which case, the surface will never be hurt by the greatest discharge; whereas the discharge of four square feet of coated glass will raise such a roughness on the surface of brass as will cause it to sputter, and destroy entirely the regularity of the expenditure of fluid. The same consideration should make us prefer a jar coated entirely with amalgam. This cob-web coating gives a greater softness to the shock. Lastly, we see why a powerful and permanent electricity was not produced in the tube filled with melted sealing wax, and treated as mentioned in n^o 101. The redundancy and deficiency intended to be produced could only be superficial. And because the wax cooled by degrees from the surface to the axis, and the wax is a conductor while liquid, it must have taken a charge at last; and therefore must appear but faintly electrical.

181. This account of the state of charged glass promises us some assistance in our attempts to conceive what passes in the excitation of glass by friction. It appears from Beccaria's experiments, that the redundant fluid is lodged in the same manner in both cases; for by rubbing one side of a glass tumbler, while points were presented to the opposite surface, and were connected with a wire that communicated with the ground, he gave it a powerful charge.

182. The quantity of fluid in a body may be exceeding great. It is observed, that when the laminæ of a piece of Muscovy glass are separated, by pulling them asunder without inserting any instrument between them, they are electrical when separated; one being positive, and the other negative. Must we not conclude from this, that when conjoined they were in the state of charged glass? If we take this view of it, a body may contain a prodigious quantity of electric fluid without exhibiting any appearance of it. Mr Nicholson found, by a very fair computation from his experiments, that a cubic inch of talc, when split into plates of 0,011 of an inch in thickness, and coated with gold leaf, gave a shock equal to the emptying 45 conductors, each seven inches in diameter and three feet long, electrified so that each gave a spark at nine inches distance. Now, the whole of this was moveable fluid, and no more than what the talc contains when unelectrified: for no more comes into the positive side than goes out of the negative side. Nay, there is no probability that the quantity moveable in our experiments bears a considerable proportion to the natural quantity. The quantity of moveable fluid in a man's body is therefore very great: and Lord Mahon is well authorised to say, that the sudden displacing of this quantity in a *returning stroke*, which has been occasioned by a discharge of a cloud in a very distant place, is fully adequate to the production of the most violent effects. But his Lordship has not attend-

ed to the circumstance, that no such displacement can happen. The accumulation that can be made in the human body is only superficial; and therefore, altho' the whole fluid of a man's body may change its place, it will not change it with the rapidity that seems necessary for the violent effects of electricity, except in the very points of communication with the surrounding bodies.

We have now seen in what sense the idio-electrics may be said to be impervious to the electric fluid. It is moved in them only to very small and imperceptible distances. When a considerable stratum is discharged, the fluid does not come from the extremity of it to the point of discharge through the glass, but through the coating. And when alternate strata of redundant fluid and redundant matter are formed, the particles in each shift their places very little, moving perpendicularly to the stratum.

183. Even this degree of obstruction has been denied by some very active electricians, who have multiplied experiments to prove that the fluid passes freely through glass, and that the theory of coated electrics is totally different from what Franklin imagines. Mr Lyons of Dover has published a numerous list of singular experiments, which he has made with this view, with much trouble, and no small expence. They may all be reduced to this: A wire is brought from the outside of a phial, charged by the knob, and terminates in a sharp point at a small distance from a thin glass plate (it is commonly introduced into a glass tube, having a ball at the end, and the point of the wire reaches to the centre of the ball); and another wire is connected with the discharging rod, and also comes very near (and frequently close) to the other side of the glass, opposite to the pointed wire. With this apparatus he obtains a discharge; and therefore says that the glass is permeable to electricity. But he does not narrate all the circumstances of the experiment. We have repeated all of them that have any real difference (for most of them are the same fact in different forms), and we have obtained discharges: But they were all very incomplete, except when the glass was perforated, which happened very frequently. The discharge was never made with a full, bright, undivided spark, and loud snap; but with sputtering, and trains of sparks, continued for a very sensible time; and the phial was never deprived of a considerable part of its charge: and (which Mr Lyons has taken no notice of) the glass is found to be charged, negative on the side connected with the positive side of the phial, and positive on the other. This charge was communicated to the glass over a pretty considerable surface round the points immediately opposite to the wires. This is quite conformable to the experiments of Dr Franklin and Beccaria, who charged a tumbler by grasping it with the hand, and presenting the inside to a point electrified by the prime conductor. The whole experiment is analogous to the one narrated in n^o 176.

185. We may conclude our observations on coated glass with mentioning a curious experiment. A flat stick of fine sealing wax, warmed till it bent pretty readily, was rendered permanently electrical, with a positive and negative pole, in a manner analogous to the double touch of magnets. A small jar was taken, having a hemisphere on the end of its inside wire, and another on the end

184. The impermeability of electrics denied by some.

185. Bars touched like magnets & electricity

end of a stiff wire projecting from the outer coating, and then turned up parallel to the inside wire; so that the two hemispheres stood equally high, and about three inches asunder. This jar was electrified so weakly, as to run no risk of a spontaneous discharge. The flat faces of the two hemispheres were now applied to the flat side of the sealing wax, and were moved to and fro along it, overpassing both ends about an inch with each hemisphere. The experiment was very troublesome; for the phial often discharged itself along the surface of the sealing wax, and all was to begin again. But, by continuing this operation till the sealing wax grew quite cold and hard, it acquired a very sensible electricism, which lasted several weeks when kept with care; but still it was not much more sensible than that of the sealing wax, which congealed between two globes oppositely electrified.

After this application of the theory to the phenomena of coated glass, it will not be necessary to employ much time in its application to the electrophorus. The general propositions from n^o 14. to 25. and their companions in n^o 38—43, will enable us to state with precision (when combined with the law of electric action) the actions of every part of this apparatus; and considerable assistance will be derived from a careful consideration of our analysis of Professor Richmann's experiment in n^o 156. But we must content ourselves with a general, popular view of these particulars, which may be sufficient for making us understand what will be the *kind*, and somewhat of the *intensity*, of the action of its different parts.

The electrophorus consists of three parts. The chief part is the cake ABCD (fig. 34.) of some electric; such as gum lac, sealing wax, pitch, or other resinous composition. This is melted on some conducting plate, DCFE, and allowed to congeal; in which state it is found to be negatively electric. Another conducting plate GHBA is laid on it, and may be raised up by silk lines, or any insulating handle. We shall call ABCD the CAKE, DCFE the SOLE, and GHBA the COVER.

The general appearances not having been so scientifically classed in the article ELECTRICITY as could be wished, we shall here narrate them, very briefly, in a way more suited to our purpose. In comparing the theory with observation, it will be proper to make all the three parts of considerable thickness, and of no great breadth. Although this diminishes greatly the most remarkable of the actions, it leaves them sufficiently vivid, and it greatly increases the smaller changes which are instructive in the comparison. The general facts are,

1. If the sole has been insulated during the congelation of the electric, till all is cold and hard, the whole is found negatively electric, and the finger draws a spark from any part of it, especially from the sole. If allowed to remain in this situation, its electricity grows gradually weaker, and at last disappears: but it may be excited again by rubbing the cake with dry warm flannel, or, which is the best, with dry and warm cat or hare fur. If the cover be now set on the cake by its insulating handle, but without touching the cover, and again separated from the cake, no electricity whatever is observed in the cover.

2. But if it be touched while on the cake, a sharp

pungent spark is obtained from it; and if, at the same time, the sole be touched with the thumb, a very sensible shock is felt in the finger and thumb.

3. After this, the electrophorus appears quite inactive, and is said to be *dead*; neither sole nor cover giving any sign of electricity. But,

4. When the cover is raised to some distance from the cake (keeping it parallel therewith), if it be touched while in this situation, a smart spark flies, to some distance, between it and the finger, more remarkably from the upper side, and still more from its edge, which will even throw off sparks into the air, if it be not rounded off. As this diminishes the desired effects, it is proper to have the edge so rounded. This spark is not so sharp as the former, and resembles that from any electrified conductor.

5. The electricity of the cover, while thus raised, is of the opposite kind to that of the cake, or is positive.

6. The electricity of the cover while lying on the cake is the same with that of the cake, or negative.

7. The appearances n^o 2, 3, 4, may be repeated for a very long time without any sensible diminution of their vivacity. The instrument has been known to retain its power undiminished even for months. This makes it a sort of magazine of electricity, and we can take off the electricity of the cake and of the cover as charges for separate jars, the cover, when raised, charging like the prime conductor of an ordinary electrical machine; and, when set on the cake, charging it like the rubber. This caused the inventor, Mr Volta, to give it the name of ELECTROPHORUS.

8. If the sole be insulated before putting on the cover, the spark obtained from the cover is not of that cutting kind it was before: but the same shock will be felt if both cake and cover be touched together.

9. If the cover be again raised to a considerable height, the sole will be found electrical, and its electricity is that of the cake, and opposite to that of the cover.

10. After touching both cover and sole, if the cover be raised and again set down, without touching it while aloft, the whole is again inactive.

11. If both cover and sole be made inactive when joined, they shew opposite electricities when separated, the sole having the electricity of the cake.

12. If both cover and sole be made inactive when separate, they both shew the opposite to the electricity of the cake when joined.

Let us now attend to the disposition of the electrical fluid in the different parts of the instrument in their various situations, and to the forces which operate mutually between them. *N. B.* Experiments for examining this instrument are best made by setting the three plates vertically, supported on glass stalks, with leaden feet, to steady them. A very small electrometer may be attached to the outer surfaces of the cover and sole.

If the extent of the plates were incomparably greater than their thickness, we may infer from n^o 92, &c. that the redundant fluid and matter would be disposed in parallel strata, and that the actions would be the same at all distances. But since this is not the case, the disposition of the fluid will be somewhat different; and whatever it is, the action of any stratum will be diminished by an increase of distance. The following description cannot be very different from the truth:

1. The cake grows negative by cooling; and if it were

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Explanation of the
primitive
state.

were alone, it would have a negative superficial stratum on both sides, of greater thickness near the edges; and the fluid would probably grow denser by degrees to the middle, where it would have its natural density. This disposition may be inferred from n^o 92, 93, and 98. But it cools in conjunction with the sole, and the attraction of the redundant matter in the cake; for the moveable fluid in the sole disturbs its uniform diffusion in the sole, and causes it to approach the cake. And because this, in all probability, happens while the cake is still a conductor, the disposition of its fluid will be different from that described above, and the final disposition of the fluid in the cake and sole will resemble that described in n^o 95, where the plates E and A represent the cake and sole. But because we do not know precisely the gradation of density, and aim only at general notions at present, it will be sufficient to consider the cake and sole as divided into two strata only; one redundant in fluid, and the other deficient, neglecting the neutral stratum that is interposed between them in each. The cake, then, consists of a stratum *ABba* containing redundant matter, and a stratum *abcd* containing redundant fluid: and the sole has a stratum *DCnm* containing redundant fluid, namely, all that belongs naturally to the space *DCFE*, and a stratum *mnFE* containing redundant matter. This may be called the *PRIMITIVE STATE* of the cake and sole; and if once changed by communication with unelectricised bodies, it can never be recovered again without some new excitement.

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Common
State.

II. If the sole be touched by any body communicating with the ground, fluid will come in, till the repulsion of the redundant fluid in the sole for a superficial particle *y* is equal to the attraction of the redundant matter in the cake for the same particle. What has been said concerning infinitely extended plates rendered neutral on one side, may suffice to give us a notion of the present disposition of the fluid in the sole. The under surface will be neutral, and the fluid will increase in density toward the surface *DC*. The sole contains more than its natural quantity of fluid, but is neutral by the balance of opposite forces. Let it now be insulated. This disposition of fluid may be called the *common state* of the electrophorus.

190.

III. Let the cover *GHBA* be laid on it. The particle *z*, at the upper surface of the cover, must be more attracted by the redundant matter in the stratum *ABba* than it is repelled by the redundant fluid in the remoter strata; for the fluid in the cake is less than what belongs to it in its natural state, and therefore *z* is attracted by the cake. The redundant fluid which has come into the remote side of the sole is less than what would saturate the redundant matter of the cake, because it only balances the excess of the remote action of this matter above the nearer action of the compressed fluid in the sole; and this smaller quantity of redundant fluid acts on *z* at a greater distance than that of the redundant matter in the cake. On the whole, therefore, the particle *z*, lying immediately within the surface *GH*, is attracted; therefore some will move toward the cake, and its natural state of uniform diffusion through the cover will be changed into a violent state, in which it will be compressed on the surface *AB*, being abstracted from the surface *GH*. It will now have a stratum *Cgph*, containing redundant matter, and another

gpBA, containing redundant fluid. But this will disturb the arrangement which had taken place in the sole, and had rendered it neutral on the under surface. We do not attend to the fluid in the cake, but consider it as immoveable; for any motion which it can get will be so small, that the variations of its action will be altogether insignificant. The particle *y*, situated in that surface, will be more repelled by the compressed fluid in the stratum *gpCA* than it is attracted by the equivalent, but more remote redundant matter in *GHpg*. Fluid is therefore disposed to quit the surface *EF*, and the sole appears positively electric; very little indeed, if the cover be thin. All this may be observed by attaching a small Canton's electrometer to the lower surface of the sole, or by touching the sole with the electrometer of fig. 8. and then trying its electricity by rubbed wax or glass.

IV. A particle of fluid *z*, placed immediately without the surface *GH*, will be more attracted by the deficient stratum *GHpg* and by *ABba* than it is repelled by the redundant strata beyond them, and the cover must be sensibly negative. This is the common state of the whole instrument after setting on the cover. It is slightly positive on the lower surface of the sole, and much more sensibly negative on the upper surface of the cover. A smart spark will therefore be seen between it and the finger, fluid will enter, till the attraction of the redundant matter in *ABba* is balanced by the repulsion of the redundant fluid in *DCFE*.

191.

V. A spark will now be obtained from the sole, because it was faintly positive before, and there has been added the action of the fluid which has entered into the cover. The fluid in the sole is therefore disposed to fly to any body presented to it. But when this has happened, the equilibrium at the surface *GH* is destroyed, and that surface again becomes negative, and will attract fluid, although the cover already contains more than its natural quantity. A small spark will therefore be seen between the cover and any conducting body presented to it. By touching it, the neutrality or equilibrium is restored at *GH*; but it is destroyed again at *EF*, which will again give a positive spark, which, in its turn, again leaves *GH* negative. This will go on for ever, in a series of communications continually diminishing, so as soon to become insensible, if the three parts of the electrophorus be thin. This makes it proper to make them otherwise, if the instrument be intended for illustrating the theory.

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Dead state.

At last the equilibrium is completed at the surfaces *GH* and *EF*, and both are neutral in relation to surrounding bodies, although both the cover and sole contain more than their natural share of electric fluid. We may call this the *NEUTRAL* or *DEAD* state of the electrophorus.

This state may be produced at once, instead of doing it by these alternate touches of *GH* and *EF*. If we touch at once both these surfaces, we have a bright, pungent spark, and a small shock. If this be the object of the experiment, the state N^o IV. which gives occasion to it, may be called the *CHARGED* state of the electrophorus.

193
Charged
state.

When the instrument has thus been rendered neutral in relation to surrounding bodies, it is plain that it may continue in this state for any length of time without any diminution of its capability of producing the other phenomena,

phenomena, provided only that no fluid pass from the cover to the cake. We do not *fully* understand what prevents this communication, nor indeed what prevents the rapid escape from an overcharged body into the air. This cause, whatever it be, operates here; and the best way of preventing the dissipation, or the absorption by the cake, is to keep the electrophorus with its cover on. It will come into this neutral state by dissipation from the sole, and absorption by the cover, in no very long time; and after this, will remain neutral, retaining its power with great obstinacy, especially if the cake and plates are very thin.

194
Charging or
active state.

VI. If the cover be now removed to a distance, both parts of the apparatus will shew strong marks of electricity. The cover contains much redundant fluid, and must appear strongly positive, and will give a bright spark, which may be employed for any purpose. It may be employed for charging a jar positively by the knob, if we just touch the cover with the knob. The sole will attract fluid, or be negative, although it contain more than its natural quantity of fluid, and it will take a spark. The sole therefore, in the absence of the cover, may be employed to charge a jar negatively by the knob. By touching it with the finger, or with the knob of a jar held in the hand, it is reduced to the common state described in N^o II.; and now all the former experiments may be repeated. We may call this the ACTIVE or the CHARGING state.

Electro-
phorus not
a magazine
of electric-
ity, but a
collecting
machine.

This state of the apparatus has caused it to get the name *Electrophorus*. Volta, its undoubted inventor, called it *Electroforo perpetuo*; for it *appears*, as has been already observed, to contain a magazine of electricity. The cover, when removed, will charge a jar held in the hand positively; and having done this service, it will charge a jar negatively when again set on the cake. The sole, in the absence of the cover, will charge a third jar negatively; and then, when the cover, after being touched, is set down again, it will charge a fourth jar positively. It will not be difficult to contrive a simple mechanism, connected with the motion of the cover, which shall connect the joined parts with two jars, and shall connect them, when separated, with two others; and thus charge all the four with great expedition. All this is done without any new excitation of the electrophorus. But it is by no means a *magazine* of electricity which it gradually expends: it is a *COLLECTOR* of electricity from the surrounding bodies, which it afterwards imparts to others, and may be employed to discharge jars in the same gradual manner as to charge them.

195.

VII. If the electrophorus is not insulated, a shock may still be obtained, by first touching the sole, and then, without removing the finger, touching the cover: but this will not be so smart as when the negative cover is touched at the same time that we touch the sole, more highly positive than when it communicates with the ground. The difference must, however, be almost imperceptible when the pieces are thin.

196.

VIII. If the electrophorus is not insulated, the cover, when put on, will give a spark in the manner already mentioned, and it will be somewhat stronger than when it is insulated; because the fluid is allowed to escape from the sole, and does not obstruct the entry into the cover. If we then, without removing the finger from the cover, touch the sole, nothing is felt; but if we first

touch the sole, and, without removing the finger from it, touch the cover, we obtain a shock. This is evident from the theory. By this series of alternate touches, the period of the electrophorus is completed. The electrophorus is charged, or rendered neutral, by touching the plates when joined; then, by touching both when separated, the whole is reduced to the common state. When separated, from being in the neutral state, they have opposite electricities, the sole shewing that of the cake. When brought together, each in the common state, they have opposite electricities, the cover shewing that of the cake.

IX. When, by long exposure to the air without its cover, the electrophorus has lost its virtue, it may be brought again into an active state in a variety of ways. Its surface may be rendered negative by friction with dry cat or hare skin, or warm flannel. It may be rendered negative by setting on it a jar charged negatively on the inside, and then touching the knob with any thing communicating with the ground. This is the most expeditious method, and will give it a high degree of excitation, if the jar be of size, and if the electrophorus be covered with a plate of tinfoil which comes into contact all over its surface. This however requires the previous charging of the jar; therefore it will be as expeditious and effectual to connect this surface with the rubber of an electrical machine. We had almost forgotten to remark, that the effects of bringing the cover edgewise to the cake follow clearly from the theory, as will appear to the attentive reader without further explanation.

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It is not si-
milar to a
charged
pane.

The electrophorus has been compared to a charged plate of coated glass. It is true that it *may be brought* into an external state which very much resembles a charged pane; namely, when the cover, in its natural state, is set on the electrophorus in its natural state: and accordingly it gives a shock, and the two exterior surfaces become neutral; but the internal constitution, and the acting forces, are totally and *essentially* different. The two coatings of the pane would not, when separated, exhibit the appearances of the electrophorus; nor, when touched in their disjointed state, will they produce the same effects when joined. In the operation of coated glass, the constant or invariable part, the glass is not the *agent*, it is merely the *occasion* of the action, by allowing the accumulation. In the electrophorus, the electric, which is the constant invariable part, is the *agent producing* the accumulation. The electrophorus is an original, and a very ingenious and curious electrical machine. Nothing has so much contributed to spread some general, though slight, acquaintance with the mechanical principles of electricity. The numerous dabbles in natural knowledge had been diverted from scientific pursuit by the variety of the singular and amusing effects of electricity, and had really attained very little connected knowledge. The effects of the electrophorus *forced* this knowledge on them; because no use can be made of it without a pretty clear conception of the disposition of the electricity, and the kind and intensity of the actions. It is therefore most ungrateful in the experimenters who have attained better views, to attempt to rob Mr Volta of the real merit of discovery, by shewing that its effects are similar to those of Mr Symmer's stockings, or of Cigna's plates, or of Franklin's charged or discharged glass panes. And the at-

tempt destroys itself: for it shews the ignorance or inattention of its author; for the similarity is not real, as will appear clear to any person who will examine things minutely and scientifically, proceeding in this examination on suppositions similar to those which we employed in the analysis of Richmann's experiment. It was indeed in subserviency to this examination that we entered into the detail of that experiment, it being a simpler case. The accurate examination of Richmann's experiment requires the fluxionary calculus in its refined form. In the present question five acting strata are to be considered, which renders the formulæ very complicated, and indeed intractable, unless we make the plates extremely thin; which, fortunately, is the best form of the instrument. We have completed this mathematical analysis; and the popular view here given is the result of that computation.

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Condensator
of electricity.

The electricians are no less obliged to Mr Volta for another machine, or instrument, from which the study of Nature's operations has derived, or may derive, immense advantages. We mean the CONDENSER or COLLECTOR of electricity. We refer to the article ELECTRICITY in the *Encyclopædia* for a description of the instrument, and some account of its effects and properties. The general effect is to render sensible an accumulation or deficiency of electric fluid so slight that it will not affect the most delicate electrometer; and it produces (at least in the opinion of Mr Volta) this effect, by employing for the sole of an electrophorus a body which is an imperfect conductor, such as a plate of well dried marble, or well dried, but not baked, wood; or even a conducting body, covered with a bit of dry taffety or other silk. Mr Volta, Cavallo, and others, who have written a great deal on the subject, have attempted to shew how these substances are preferable (and they certainly are preferable in a high degree) to more perfect insulators: but not having taken pains to form precise notions of the disposition and action of the electric fluid in the situations afforded by the instrument, their reasonings have not been very clear. We think that an adequate conception of the essentials of the proposed instrument may be acquired by means of the following considerations:

200.

Furnish the cover of an electrophorus with a graduated electrometer, which indicates the proportional degrees of electricity; electrify it positively to any degree, suppose six, while held in the hand, at some distance, right over a metal plate lying on a wine glass as an insulating stand, but communicating with the ground by a wire. Bring it gradually down toward the plate. Theory teaches, and we know it by experiment, that the electrometer will gradually subside, and perhaps will reach to 2° before the electricity is communicated in a spark. Stop it before this happens. In this state the attraction of the lying plate produces a compensation of four degrees of the mutual repulsion of the parts of the cover, by dissipating the fluid on its under surface, and forming a deficient stratum above. This needs no farther explanation after what has been said on the charging of coated glass plates. Now we can suppose that the escape of the fluid from this body into the air begins as soon as electrified to the degree 6, and that it will fly to the lying plate with the degree 2, if brought nearer. If we can prevent this communication to the lying plate, by interposing an

electric, we may electrify the cover again, while so near the metal plate, to the degree 6, before it will stream off into the air. If it be now removed from the lying plate, the fluid would raise the electrometer to 10, did it not immediately stream off; and an electric excitement of any kind which could only raise this body to the degree 6 by its intensity, will, by this apparatus, raise it to the degree 10, if only copious enough in extent. If we do the same thing when the wire is taken away which connects the lying plate with the ground, we know that the same diminution of the electricity of the other plate cannot be produced by bringing it down into the neighbourhood of the lying plate (see n° 134, &c. 151, &c.)

Here we see the whole theory of Mr Volta's condenser. He seems to have obscured his conceptions of it by having his thoughts running upon the electrophorus lately invented by him, and is led into fruitless attempts to explain the advantages of the imperfect conductor above the perfect insulator. But the apparatus is altogether different from an electrophorus, and is more analogous in its operations to a coated plate not charged nor insulated on the opposite side; and such a coated plate lying on a table is a complete condenser, if the upper coating be of the same size with the plate of the condenser. All the directions given by Mr Volta for the preparation of the imperfect conductors shew, that the effect produced is to make them as perfect conductors as possible for any degree of electricity that exceeds a certain small intensity, but such as shall not suffer this very weak electricity to clear the first step of the conduit. The marble must be thoroughly dried, and even heated in an oven, and either used in this warm state, or varnished, so as to prevent the reabsorption of moisture. We know that marble of slender dimensions, so as to be completely dried throughout, will not conduct till it has again become moist. A thick piece of marble is rendered so, superficially only, and still conducts internally. It is then in the best possible state. The same may be said of dry unbaked wood. Varnishing the upper surface of a piece of marble or wood is equivalent to laying a thin glass plate on it. Now this method, or covering the top of the marble, or of a book, or even the table, with a piece of clean dry silk, makes them all the most perfect condensators. This just view of the matter has great advantages. It takes away the mysterious indistinctness and obscurity which kept the instrument a quackish tool, incapable of improvement. We can now make one incomparably better and more simple than any proposed by the very ingenious inventor. We need only the simple moveable plate. Let this be varnished on the under side with a moderately thick coat of the purest and hardest *vernis de Martin*, or coach-painters varnish; and we have a complete condenser by laying this on a table. If it be connected by a wire with the substance in which the weak and imperceptible electricity is excited, it will be raised (provided there be enough of it of that small intensity) in the proportion of the thickness of the varnish to the fourth part of the diameter of the plate. This degree of condensation will be procured by detaching the connecting wire from the insulating handle of the condenser, and then raising the condenser from the table. It will then give sparks, though the original electricity could not sensibly affect a flaxen fibre.

It must be particularly noted, that it can produce this condensation only when there is fluid to condense; that is, only when the weak electricity is diffused over a greater space than the plate of the condenser. In this way it is a most excellent collector of the weak atmospheric electricity, and of all diffused electricity. But to derive the same advantage from it in many very interesting cases, such as the inquiry into the electricity excited in many operations of Nature on small quantities of matter, we must have condensers of various sizes, some not larger than a silver penny. To construct these in perfection, we must use the purest and hardestst varnish, of a kind not apt to crack, and highly coercive. This requires experiment to discover it. Spirit varnishes are the most coercive; but by their difference of contraction by cold from that of metals, they soon appear frosty, and when viewed through a lens, they appear all shivered: They are then useless. Oil varnishes have the requisite toughness; but are much inferior in coercion. We have found amber varnish inferior to copal varnish in this respect, contrary to our expectation. On the whole, we should prefer the finest coach-painters varnish, new from the shop, into which a pencil has never been dipped: and we must be particularly careful to clear our pencils of moisture and all conducting matter, which never fails to taint the varnish. We scarcely need remark, that the coat of varnish on these small condensers should be very thin, otherwise we lose all the advantage of their smallness.

201.
Cavallo's
improvement
thereof.

Mr Cavallo has ingeniously improved Volta's condenser by connecting the moveable plate, after removal, with a smaller condenser. The effect of this is evident from n° 130. But the same thing would have been generally obtained by using the small condenser at first, or by using a still thinner coat of varnish.

202.

It will readily occur to the reader, that this instrument is not instantaneous in its operation, and that the application must be continued for some time, in order to collect the minute electricity which may be excited in the operations of nature. He will also be careful that the experiment be so conducted that no useless accumulation is made anywhere else. When we expect electricity from any chemical mixture, it never should be made in a glass vessel, for this will take a charge, and thus may absorb the whole excited electricity, accumulating it in a neutral or insensible state. Let the mixture be made in vessels of a conducting substance, insulated with as little contact as possible with the insulating support; for here will also be something like a charge. Suspend it by silk threads, or let it rest on the tops of three glass rods, &c.

203.
Bennet's
doubler of
electricity.

After this account of the Leyden phial, electrophorus, and condenser, it is surely unnecessary to employ any time in explaining Mr Bennet's most ingenious and useful instrument called the *doubler of electricity*. The explanation offers itself spontaneously to any person who understands what has been said already. Mr Cavallo has with industry searched out all its imperfections, and has done something to remove them, by several very ingenious constructions, minutely described in his *Treatise on Electricity*. Mr Bennet's original instrument may be freed, we imagine, as far as seems possible, by using a plate of air as the intermedium between the three plates of the doubler. Stick on one of the plates three very small spherules made from a capillary tube of glass,

or from a thread of sealing wax. The other plate being laid on them, rests on mere points, and can scarcely receive any friction which will disturb the experiment. Mr Nicholson's beautiful mechanism for expediting the multiplication, has the inconvenience of bringing the plates towards each other edgewise, which will bring on a spark or communication sooner than may be desired: but this is no inconvenience whatever in any philosophical research; because, before this happens, the electricity has become very distinguishable as to its kind, and the degree of multiplication is little more than an amusement. The spark may even serve to give an indication of the original intensity, by means of the number of turns necessary for producing it. If the fine wires, which form the alternate connections in so ingenious a manner, could be tipped with little balls to prevent the dissipation, it would be a great improvement indeed. An alternate motion, like that of a pump-handle, might be adopted with advantage. This would allow the plates to approach each other face to face, and admit a greater multiplication, if thought necessary.

One of the most remarkable facts in electricity is the rapid dissipation by sharp points, and the impossibility of making any considerable accumulation in a body which has any such, projecting beyond other parts of its surface. The dissipation is attended with many remarkable circumstances, which have greatly the appearance of the actual escape of some material substance. A stream of wind blows from such a point, and quickly electrifies the air of a room to such a degree, that an electrometer in the farthest corner of the room is affected by it. This dissipation in a dark place is, in many instances, accompanied by a bright train of light diverging from the point like a firework. Dr Franklin therefore was very anxious to reconcile this appearance with his theory of plus and minus electricity, but does not express himself well satisfied with any explanation which had occurred to him. From the beginning, he saw that he could not consider the stream of wind as a proof of the escape of the electric fluid, because the same stream is observed to issue from a sharp negative point; which, according to his theory, is not dispersing, but absorbing it. Mr Cavendish has, in our opinion, given the first satisfactory account of this phenomenon.

204.
Dissipation
of electricity
from
sharp
points.

To see this in its full force, the phenomenon itself must be carefully observed. The stream of wind is plainly produced by the escape of something from the point itself, which hurries the air along with it; and this draws along with it a great deal of the surrounding air, especially from behind, in the same manner as the very slender thread of air from a blow-pipe hurries along with it the surrounding air and flame from a considerable surface on all sides. It is in this manner that it gathers the whole of a large flame into one mass, and, at last, into a very point. If the smoke of a little rosin thrown on a bit of live coal be made to rise quietly round a point projecting from an electrified body, continually supplied from an electrical machine, the vortices of this smoke may be observed to curl in from all sides, along the wire, forming a current of which the wire is the axis, and it goes off completely by the point. But if the wire be made to pass through a cork fixed in the bottom of a wide glass tube, and if its point project not beyond the mouth of the tube,

205.

the

the afflux of the air from behind is prevented, and we have no stream; but if the cork be removed, and the wire still occupy the axis of the tube, but without touching the sides, we have the stream very distinctly; and smoke which rises round the far end of the tube is drawn into it, and goes off at the point of the wire. Now it is of importance to observe, that whatever prevents the formation of this stream of wind prevents the dissipation of electricity (for we shall not say escape of electric fluid) from the point. If the point project a quarter of an inch beyond the tube, or if the tube be open behind, the stream is strong, and the dissipation so rapid, that even a very good machine is not able to raise a Henly's electrometer, standing on the conductor, a very few degrees. If the tube be slipped forward, so that the point is just even with its mouth, the dissipation of electricity is next to nothing, and does not exceed what might be produced by such air as can be collected by a superficial point. If the tube be made to advance half an inch beyond the point which it surrounds, the dissipation becomes insensible. All these facts put it beyond a doubt that the air is the cause, or, at least, the occasion of the dissipation, and carries the electricity off with it, in this manner rendering electrical the whole air of a room. The problem is reduced to explain how the air contiguous to a sharp electrified point is electrified and thrown off.

Theory of
it.

It was demonstrated in n° 130, that two spheres, connected by an infinitely extended, but slender conducting canal, are in electrical equilibrium, if their surfaces contain fluid in the proportion of their diameters. In this case, the superficial density of the fluid and its tendency to escape are inversely as the diameters (n° 130). Now if, in imagination, we gradually diminish the diameter of one of the spheres, the tendency to escape will increase in a greater proportion than any that we can name. We know, that when the prime conductor of a powerful table-machine has a wire of a few inches in length projecting from its end, and terminating in a ball of half an inch in diameter, we cannot electrify it beyond a certain degree; for when arrived at this degree, the electricity flies off in successive bursts from this ball. Being much more overcharged than any other part of the body, the air surrounding the ball becomes more overcharged by communication, and is repelled, and its place supplied by other air, not so much overcharged, which surrounded the other parts of the body, and is pressed forwards into this space by the general repulsion of the conductor and the confining pressure of the atmosphere; otherwise, being also overcharged, it would have no tendency to come to this place. Half a turn of the cylinder is sufficient to accumulate to a degree sufficient for producing one of these explosions, and we have two of them for every turn of the cylinder. A point may be compared to an incomparably smaller ball. The constipation of the fluid, and its tendency to escape, must be greater in the same unmeasurable proportion. This density and mutual repulsion cannot be diminished, and must even be increased, by the matter of the wire forming a cone of which the point is the apex; therefore, if there were no other cause, we must see that it is almost impossible to confine a collection of particles, mutually repelling, and constipated, as these are in a fine point.

But the chief cause seems to be a certain chemical

union which takes place between the electric fluid and a corresponding ingredient of the air. In this state of constipation, almost completely surrounded by the air, the little mass of fluid must attract and be attracted with very great force, and more readily overcome the force which keeps the electrified fluid attached to the last series of particles of the wire. It unites with the air, rendering it electric in the highest degree of redundancy. It is therefore strongly repelled by the mass of constipated fluid which succeeds it within the point. Thus is the electrified air continually thrown off, in a state of electrification, that must rapidly diminish the electricity of the conductor. Hence the uninterrupted flow, without noise or much light, when the point is made very fine. When the point is blunt, a little accumulation is necessary before it attains the degree necessary for even this minute explosion; but this is soon done, and these little explosions succeed each other rapidly, accompanied by a sputtering noise, and trains of bright sparks. The noise is undoubtedly owing to the atoms of the highly electrified fluid. These are, in all probability, rarefied of a sudden, in the act of electrification, and immediately collapse again in the act of chemical union, which causes a sonorous agitation of the air. This electrified air is thus thrown off, and its place is immediately supplied by air from behind, not yet electrified, and therefore strongly drawn forward to the point, from which they are thrown off in their turn. This rapid expansion and subsequent collapsing of the air is verified by the experiments of Mr Kinnerly, related by Dr Franklin, and is seen in numberless experiments made with other views in later times, and not attended to. Perhaps it is produced by the great heat which accompanies, or is generated in the transference of electricity; and it is of the same kind with what occasions the bursting of stones, splitting of trees, exploding of metals, &c. by electricity. The expansion is either inconsiderable, or it is successively produced in very small portions of the substance expanded; for when metal is exploded in close vessels, or under water, there is but a minute portion of gaseous matter produced, and in the dissipation by a very fine point, sufficiently great to give full employment to a powerful machine, the stream of wind is but very faint, and nine-tenths of this has been dragged along by the really electrified thread of wind in the middle.

From a collation of all the appearances of electricity, we must form the same conception of the forces which operate round a point that is negatively electrified, not dispersing, but drawing in electric fluid. It is more completely undercharged than any other part of a body, and attracts the fluid in the surrounding air, and the air in which it is retained, with incomparably greater force. It therefore deprives the contiguous air of its fluid, and then repels it, and then produces a stream like the overcharged point.

If a conducting body be brought near to any part of an overcharged body, the fronting part of the first is rendered undercharged; and this increases the charge of the opposite part of the overcharged body. It becomes more overcharged in that part, and sooner attains that degree of constipation that enables the fluid to quit the superficial series of particles, and to electrify strongly the contiguous air. The explosion is therefore made in this part in preference to any other; and

the

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electricity
unites chemically
with air.

207.

the air thus exploded is strongly attracted by the fronting part of the other body, and must fly thither in preference to any other point. If, moreover, the fronting part of A be prominent or pointed, this effect will be produced in a superior degree; and the current of electrified air, which will begin very early, will increase this disposition to transference in this way by rarefying the air; a change which the whole course of electric phenomena shews to be highly favourable to this transference, although we cannot perhaps form any very adequate notion how it contributes to this effect. This seems to be the reason why a great explosion and snap, with a copious transference of electricity, is generally preceded by a hissing noise like the rushing of wind, which swells to a maximum in the loud snap itself.

208.

If two prominences, precisely similar, and electrified in the contrary way to the same degree, are presented to each other, we cannot say from which the current should take its commencement, or whether it should not equally begin from both, and a general dispersion of air laterally be the effect; but such a situation is barely possible, and must be infinitely rare. The current will begin from the side which has some superiority of propelling force. We are disposed to think that this current of material electrified substance must suffer great change during its passage, by mixing with the current in an opposite electrical state coming from the other body. Any little mass of the one current must strongly attract a contiguous mass of the other, and certain changes should surely arise from this mixture. These may, in their turn, make a great change in the *mechanical* motions of the air; and, instead of producing a *quæqua versum* dispersion of air from between the bodies, as should result from the meeting of opposite streams, it may even produce a collapsing of the air by the mutual strong attractions of the little masses. Many valuable experiments offer themselves to the curious inquirer. Two little balls may be thus presented to each other, and a smoke may be made with rosin to occupy the interval between them. Motions may be observed which have certain analogies that would afford useful information to the mechanical inquirer. There must be something of this mixture of currents in all such transferences, and the most minute differences in the condition of a little parcel of the air may greatly affect the future motions. The most promising form of such experiment would be to use two points of the same substance, shape, and size, and electrified to the same degree in opposite senses.

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Characteristic differences of positive and negative electricity.

After all care has been taken to insure similarity, there remains one essential difference, that *the one current is redundant in electric fluid, and the other deficient*. This circumstance *must* produce characteristic differences of appearance. And are there not such differences? Is not the pencil and the star of light a characteristic difference? And does not this well-supported fact greatly corroborate the opinion of Dr Franklin, that the electric phenomena result from the redundancy and deficiency of *one* substance, and not from two distinct substances operating in a similar manner? For the distinction in appearance is a mechanical distinction. Motion, direction, velocity, are perceivable in it. Locomotive forces are concerned in it; but they are so implicated with forces which probably resemble chemical affinities, hardly operating be-

yond contact, that to extricate their effects from the complicated phenomenon seems a desperate problem. There is some hitherto inexplicable chemical composition and decomposition taking place in the transference of electricity. Of this a numerous train of observations made since the dawn of the pneumatic chemistry leaves us no room to doubt. The emission or production of light and heat is a remarkable sign and proof. Now *this takes place along the whole path of transference*; therefore the process is by no means completed at the point from which the active cause proceeds; and although there be certain appearances that are pretty regular, they are still mixed with others of the most capricious anomaly. The zigzag form of the most condensed spark, totally unlike, by its sharp angles, to any motions producible by accelerating forces, which motions are, without exception, curvilinear, makes us doubt exceedingly whether the luminous lines which we observe are successive appearances of the same matter in different places, or whether they be not rather simultaneous, or nearly simultaneous, coruscations of different parcels of matter in different places, indicating chemical compositions taking place almost at once; and this becomes more probable, when we reflect on what has been said already of the jumbling of opposite currents; such mixtures should be expected. We have seen a darted flash of lightning which reached (in a direction nearly parallel to the horizon) above three miles from right to left; and it seemed to us *to be co-existent*; we could not say at which end it began. The thunder began with a loud crack, and continued with a most irregular rumbling noise about 15 seconds, and seemed equal on both hands. We imagine that it was really a simultaneous snap, in the whole extent of the spark, but of different strength in different places; different portions of the sonorous agitation were propagated to the ear in succession by the sonorous undulations of air, causing it to seem a lengthened sound. Such would be the appearance to a person standing at one end of a long line of soldiers who discharge their firelocks at one instant. It will seem a running fire, of different strength in different parts of the line, if the muskets have been unequally loaded. It is inconceivable that this long zigzag spark can mark the track of an individual mass of electrified air. The velocity and momentum would be enormous, and would sweep off every thing in its way, and its path could not be angular. The same must be asserted of the streams of light in our experiments. The velocity is so unmeasurable that we cannot tell its direction. There may be very little local motion, just as in the propagation of sound, or of a wave on the surface of water. That particular change of mutual situation among the adjoining atoms which occasions chemical solution or precipitation may be produced in an instant, over a great extent, as we know that a parcel of iron filings, lying at random on the surface of quicksilver, will, in one instant, be arranged in a certain manner by the mere neighbourhood of a magnet. Is not this like the simultaneous precipitation of water along the whole path of a discharge?

But still there must be some cause which gives these simultaneous coruscations a situation with respect to each other, that has a certain regularity. Now the luminous *trains* (for they are not uniform *lines* of light) of almost continuous sparks which are arranged between

a positive and a negative point, seem to us to indicate emanation from the positive, and reception by the negative point. The general line has a considerable resemblance to the path of a body projected from the positive point, repelled by it, and attracted by the negative point. This will appear to the mechanic on a very little reflection. If the curve were completely visible, it would somewhat resemble those drawn between P and N in fig. 35. PABN overpasses the point N, and comes to it from behind; PabN lies within the other, and arrives in a direction nearly perpendicular to the axis; PaBN describes a straight line, and arrives in the direction PN. As the chemical composition advances, the light is disengaged or produced, and therefore the appearances are more rare as we advance farther in the direction in which they are produced; and there would perhaps be no appearance at all at the point where the motion ends, were it not that the few remaining parcels, where the compositions or decompositions have not been completed, are crowded together at the negative point, incomparably more than in any other part of the track. We think that these considerations offer some explanation of the appearance of the pencil and star, which are so uniformly characteristic of the positive and negative electricities; but we see many grounds of uncertainty and doubt, and offer it with due diffidence.

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Lichtenberg's electric writing affords distinctive marks of + and -

The curious figures observed by Mr Lichtenberg, formed by the dust which settles on a line drawn on the face of a mirror by the positive and by the negative knobs of a charged jar, are also uniformly characteristic of the two electricities. These are mechanical distinctions, indicating certain differences of accelerating forces. We must refer the curious reader to Lichtenberg's *Dissertations in the Göttingen Commentaries*; to the *Publication of the Haarlem Society*; to the *Gotha Magazine*; to *Dissertations by Spath* at Altdorf, and other German writers.

211
Diffipation of electricity into the air is proportional to the density.

It only remains for us to take notice of the general laws of the diffipation of electricity into the air, and along imperfect insulators. On this subject we have some valuable experiments of Mr Coulomb, published in the *Memoirs of the Academy of Sciences of Paris* for 1785.

These experiments were made with the assistance of an electrometer of a particular construction, which shall be described under the article ELECTROMETER.

The general result of Mr Coulomb's experiments was, that the momentary diffipation of moderate degrees of electricity is proportional to the degree of electricity at the moment. He found that the diffipation is not sensibly affected by the state of the barometer or thermometer; nor is there any sensible difference in bodies of different sizes or different substances, or even different figures, provided that the electricity is very weak.

212.

But he found the diffipation greatly affected by the different states of humidity of the air. Saussure's hygrometer has its scale distinctly related to the quantity of water dissolved in a cubic foot of the air. The following little Table shews an evident relation to this in the diffipation of electricity:

Hygrometer.	Grains water in cubic foot.	Diffipation per minute.
69	6,197	35
75	7,295	41
80	8,045	45
87	9,221	48

Hence it follows, that the diffipation is very nearly in the triplicate ratio of the moisture of the air. Thus if

$$\frac{69}{41} \text{ be considered as } = \frac{7,197^m}{6,180} \text{ we have } m = 2,764$$

$$\frac{69}{41} \text{ } = \frac{8,045^m}{6,180} \text{ gives } m = 2,76$$

$$\frac{69}{41} \text{ } = \frac{9,220^m}{6,180} \text{ gives } m = 3,61$$

Hence, at a medium, $m = 3,40$.

We should have observed, that the ingenious author took care to separate this diffipation by immediate contact with the air, from what was occasioned by the imperfect insulation afforded by the supports.

It must also be remarked here, that the immediate object of observation in the experiments is the diminution of repulsion. This is found to be, in any given state of the air, a certain proportion of the whole repulsion at the moment of diminution: but this is double of the proportion of the density of the electric fluid: for it must be recollected, that the repulsions by which we judge of the diffipation are mutual, exerted by every particle of fluid in the ball *t* of Coulomb's electrometer, on every particle in the ball *a*. It is therefore proportional to the electric density of each; and therefore, during the whole diffipation, the densities retain their primitive proportion; therefore, the diminution of the repulsion being as the diminution of the products of the densities, it is as the diminution of the squares of either. If therefore the density be represented by *d*, the mutual repulsion is representable by d^2 , and its momentary diminution by the fluxion of d^2 ; that is, by $2d \dot{d}$, or $2\dot{d} \times d$. Now $2\dot{d} \times d$ is to d^2 as $2\dot{d}$ is to d ; and therefore the diminution of repulsion observed in our experiment bears to the whole repulsion twice as great a proportion as the diminution of density, or the quantity of fluid diffipated bears to the whole quantity at the moment. For example, if we observe the repulsion diminished $\frac{1}{8}$, we conclude that $\frac{1}{8}$ of the fluid has escaped.

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Diminution of repulsion is double of the diffipation.

Mr Coulomb has not examined the proportion between the diffipations from bodies of different sizes. A great and a small sphere, communicating by a very long canal, have superficial densities, and tendencies to escape, inversely proportional to the diameters. A body of twice the diameter has four times the surface; and tho' the tendency to escape be twice as small, the surface is four times as great. Perhaps the greater surface may compensate for the smaller density, and the quantity of fluid actually gone off may be greater in a large sphere. This may be made the subject of trial.

214.

It must be kept in mind, that the law of diffipation ascertained by these experiments, relates to one given state of the air, and that it does not follow that in another state, containing perhaps the same quantity of water, the diffipation shall be the same. The air is such

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Diffipation depends on the state of the air.

a hete-

a heterogeneous and variable compound, that it may have very different affinities with the electric fluid. Mr Coulomb thought that he should infer from his numerous experiments, that the dissipation did not increase in the ratio of the cube of the water dissolved in the air, unless it was nearly as much as it could dissolve in that temperature. This indeed is conformable to general observation: for air is thought dry when it dries quickly any thing exposed to it; that is, when not nearly saturated with moisture. Now it is well known, that what is thought dry air is favourable to electricity.

The dissipation along imperfect insulators is brought about in a way somewhat different from the manner of its escaping by electrifying the contiguous air and going off with it. It seems to be chiefly, if not solely, along the surface of the insulating support that the electricity is diffused, and that the diffusion is produced there chiefly by the moisture which adheres to it. It is not very easy to form a clear notion of the manner, but Mr Coulomb's explanation seems as satisfactory as any we have seen.

Water adheres to all bodies, sticking to their surfaces. This adhesion prevents it from going off when electrified; and it is therefore susceptible of a higher degree of electrification. If we suppose that the particles of moisture are uniformly disposed along the surface, leaving spaces between them, the electricity communicated to one particle must attain a certain density before it can fly across the insulating interval to the next. Therefore, when such an imperfect conductor is electrified at one end, the electricity, in passing to the other, will be weakened at every step. If we take three adjacent particles *a, b, c*, of this conducting matter, we learn, from n^o 105, that the motion of *b* is sensibly affected only by the difference of *a* and *c*; and therefore that the passage of electricity from *b* to *c* requires that this difference be superior or equal to the force necessary for clearing this coercive interval. Let a particle pass over. The electric density of the particle *b* of conducting matter is diminished, while the density of the particle on the other side of *a* remains as before. Therefore some will pass from *a* to *b*, and from the particle preceding *a* to *a*; and so on, till we come to the electrified end of this imperfect insulator. It is plain from this consideration, that we must arrive at last at a particle beyond *c*, where the whole repulsion of the preceding particle is just sufficient to clear this interval. Some will come over, whose repulsion, now acting in the opposite direction, will hinder any fluid from supplying its place in the particle which it has quitted. Here the transference will stop, and beyond this the insulation is complete. There is therefore a mathematical relation between the insulating power and the length of the canal, which may be ascertained by our theory; and thus another opportunity obtained for comparing it with observation. That this investigation may be as simple as possible, we may take a very probable case, namely, where the insulating, or, to name it more graphically, the coercive, interval is equal in every part of the canal.

Let *R* be the coercive power of the insulator; that is, let *R* be the force necessary for clearing the coercive interval. Let a ball *C* (fig. 36.) be suspended by a silk thread *AB*, and let *C* represent the quantity of its redundant fluid; and let the density in the different points of the canal be as the ordinates *AD*, *Pd*, &c. of some curve line *DdB*, which cuts the axis in *B* where the

thread begins to insulate completely. Let *Pp* be an element of the axis. Draw the ordinate *pf*, the tangent *dfF*, and the normal *dE*, and *fe* perpendicular to *Pd*. Let *AC* be = *r*, *AP* = *x*, *Pd* = *y*. Then *Pp* = *x*, and *de* = - *y*. We have seen that the only sensible action on the particle of fluid in *P* is —

$\frac{yy}{x}$ (see n^o 105), when the action of the redundant fluid in the globe on the particle *P*, having the density *y*, is represented by $\frac{Cy}{(r+x)^2}$. Therefore we have $\frac{yy}{x}$ =

R, the coercive power of the thread. This is supposed to be constant. Therefore $\frac{Pd \times de}{Pp}$ is equal to some constant line *R*. But *Pp*, or *fe:de* = *Pd:PE*. Therefore the subnormal *PE* is a constant line. But this is the property of the parabola alone; and the curve of density *DdB* is a parabola, of which the parameter is 2 *PE*, or 2 *R*.

Cor. 1. The densities in different points of an imperfect insulator are as the square roots of their distance from the point of complete insulation: For *Pd*² : *AD*² = *BP* : *BA*.

2. The length of canal required for insulating different densities of electricity are as the squares of the densities. For *AB* = $\frac{AD^2}{2PE}$; and *PE* has been shown

to be a constant quantity. Indeed we see in the demonstration, that *BP* would insulate a ball, whose electric density is *Pd*, and *BA:BP* = *AD*² : *Pd*².

3. The length necessary for insulation is inversely as the coercive force of the canal, and may be represented generally by $\frac{D^2}{R}$. For *AB* is = $\frac{DA^2}{2PE} = \frac{D^2}{2R}$.

Mr Coulomb has verified these conclusions by a very satisfactory series of experiments, by the assistance of his delicate electrometer, which is admirably suited for this trial. The subject is so interesting to every zealous student of electricity, that Mr Canton, Dr B. Wilson, Mr Waitz, Wilcke, and others, have made experiments for establishing some measure of the conducting powers of different substances. It was one of the first things that made the writer of this article suppose that electric action was in the inverse duplicate ratio of the distances: for, as early as 1763, he had found that the lengths of capillary tubes necessary for insulation were as the squares of the repulsions of the ball which they insulated. The mode of reasoning offers of itself, and the fluxionary expression of the insulating power,

viz. $\frac{dd}{x}$ led immediately to a force proportional to $\frac{1}{x^2}$.

Numerous experiments were made, which we do not give here, because the public are already possessed of those of Mr Coulomb.

This discussion explains, in a satisfactory manner, the operation of the condenser, as described by Mr Volta. The weak degrees of electricity, which are rendered sufficiently sensible by the insulation of the plate of dry marble, are completely insulated by the perhaps thin stratum that has been sufficiently dried, while the rest conducts with an efficacy sufficient for permitting the accumulation.

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Dissipation
by imper-
fect insula-
tors.

Procedure
thereof.

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Theory
thereof.

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Variation
of density
in the insu-
lator.

219
Length nec-
essary for
insulation
= density².

220
Also =
 $\frac{1}{coercion}$.

Explana-
tion of the
efficacy of
Volta's con-
denser.

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When we reflect on the theory now delivered, we see that the formulæ determine the distribution of the fluid along an imperfect conductor in a certain manner, on the supposition that a *certain determinate* dose has been imparted to the ball: Because this dose, by diffusing itself from particle to particle of the conducting matter, will diffuse itself all the way to B, in such a manner that the repulsion shall everywhere be in equilibrium with the *maximum* of the coercive force of the insulating interval. But it must be farther noticed, that this resistance is not *active*, but coercive, and we may compare it to friction or viscosity. Any repulsion of electric fluid, which falls short of this, will not disturb the stability of the fluid spread along the canal, according to any law whatever. So that if AD represent the electric density of the globe, and remain constant,

any curve of density will answer, if $\frac{d\dot{d}}{x}$ be everywhere

less than R. It is therefore an indeterminate problem to assign, in general, the disposition of fluid in the canal. The density is as the ordinates of a parabola only on the supposition that the maximum of R is everywhere the same. And, in this case, the distances AB is a minimum: for, in other cases of density, we must have

$\frac{d\dot{d}}{x}$ less than R. If, therefore, we vary a single element of the curve D d B, in order that the stability of the fluid may not be disturbed, having \dot{d} constant, we must necessarily have x larger, that $\frac{d\dot{d}}{x}$ may still be less

than R; that is, we must lengthen the axis.

We see also, that to ascertain the distribution in a conducting canal is a determinate problem; whereas, in imperfect conductors, it is indeterminate, but limited by the state of the fluid, when it is so disposed that in every point the action of the fluid is in equilibrium with the maximum of resistance. This consideration will be applied to a valuable purpose in the article MAGNETISM.

This doctrine gives, in our opinion, a very satisfactory explanation of the curious observations of Mr Brookes and Mr Cuthbertson, mentioned in n^o 167. namely, that damping the inside of a coated jar diminishes the risk of explosion, and enables it to hold a higher charge. We learn here, that there is no density so great but that the least imperfect conductor will insulate it, if long enough; and that the coercive quality of an imperfect conductor may be conceived so constituted from A towards B, that the densities shall diminish in any ratio that we please, so that the variation of density (the cause of motion) may everywhere, even to the insulating point B, be very small. However great the constipation at the edge of the metallic coating may be, an imperfect conductor may be continued outward from that edge, and may be so constituted, that the constipation shall diminish by such gentle gradations, that an explosion shall be impossible. An uniform dampness will not do this, but it will diminish the abruptness of the variation of density. The state of density beyond the edge of the coating of a charged jar, very clean and dry, may be represented by the parabolic arch *Dia*. This may be changed by damping, or properly dirtying (to use Mr Brookes's phrase), to *DfB*; which is evidently preferable. We

think it by no means difficult to contrive such a continuation of imperfectly conducting coating. Thus, if gold leaf can be ground to an impalpable powder, it may be mixed with an oil varnish in various proportions. Zones of this gold varnish may be drawn parallel to the edge of the coating, decreasing in metal as they recede from the edge. By such contrivances it may be possible to increase the retentive power to a great degree.

This doctrine farther teaches us, that many precautions must be taken when we are making experiments from which measures are to be deduced; and it points them out to the mathematician. In particular, when bodies, supported by insulators, are electrified to a high degree, the supports may receive a quantity of fluid, which may greatly disturb the results; and this quantity, by exerting but a weak action on the parts of the canal, may continue for a very long time, and not be removed but with great difficulty. In such cases, it will be necessary to use new supports in every experiment. Not knowing, or not attending to this circumstance, many erroneous opinions have been formed in some delicate departments of electrical research.

Mr Coulomb's experiments on this subject are chiefly valuable for having stated the relation between the intensity of the electricity, or, as he expresses it, the electric density, and the lengths of support necessary for the complete insulation. But, as the absolute intensities have all been measured by his electrometer, and he has not given its particular scale, we cannot make much use of them till this be done by some electrician.

Mr Coulomb found that a thread of gum lac was the most perfect of all insulators, and is not less than ten times better than a silk thread as dry as it can be made, if we measure its excellence by its shortness. In a considerable number of experiments, he found that a thread of gum lac, of 1,5 inches long, insulated as well as a fine silk thread of 15 inches. When the thread of silk was dipped in fine sealing-wax, it was equal to the pure lac, if six inches long, or four times its length. If we measure their excellence by the intensities with which they insulate, lac is three times better than the dry thread, and twice as good as the thread dipped in sealing-wax: so that a fibre of silk, even when included in the lac, diminishes its insulating power. We also learn that the dissipation along these substances is not entirely owing to moisture condensed or adherent on their surfaces, but to a small degree of conducting power. We have repeated many of these experiments, and find that the conducting power of silk thread depends greatly on its colour. When of a brilliant white, or if black, its conducting power seems to be the greatest, and a high golden yellow, or a nut brown, seemed to be the best insulators; doubtless the dyeing drug is as much concerned as the fibre.

Glass, even in its dryest state, and in situations where moisture could have no access to it, *viz.* in vessels containing caustic alkali dried by red heat, or holding fresh made quicklime, appeared in our experiments to be considerably better than silk; and where drawn into a slender thread, and covered with gum lac (melted), insulated when three times the length of a thread of lac; but we found at the same time, that extreme fineness was necessary, and that it dissipated in proportion to the square of its diameter. It was remarkably hurt by having a bore, however fine, unless the bore could also

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Cautions in deducing measures from experiments.

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Insulating powers of various substances.

222
Explanation of a curious and important fact; and method of increasing a charge.

be coated with lac. Human hair, when completely freed from every thing that water could wash out of it, and then dried by lime, and coated with lac, was equal to silk. Fir, and cedar, and larch, and the rose-tree, when split into filaments, and first dried by lime, and afterwards baked in an oven which just made paper become faintly brown, seemed hardly inferior to gum lac.

The *white woods*, as they are called, and mahogany, were much inferior. Fir baked, and coated with melted lac, seems therefore the best support when strength is required. The lac may be rendered less brittle by a minute portion of pure turpentine, which has been cleared of water by a little boiling, without sensibly increasing its conducting power. Lac, or sealing wax, dissolved in spirits, is far inferior to its liquid state by heat.

These observations may be of use for the construction of electrical machines of other electricians than glass.

to stagger our belief in the existence of a fluid *sui generis*, a fire, heat, caloric, or what we please to call it; and all will acknowledge, that no better proofs can be urged for the existence of an electric fluid.

Accordingly, many acute and ingenious persons have rejected the notion of the existence of an electric fluid, and have attempted to shew that the phenomena proceed, not from the presence of a peculiar substance, but from peculiar modes; as we know that sound, and some concomitant motions and other mechanical appearances, are the results of the elastic undulations of air; and as Lord Bacon and others have explained the effects of fire by elastic undulations of the integrant particles of tangible matter.

We have seen nothing, however, of this kind that appears to give any explanation of the motions, pressures, and other mechanical appearances of electricity. We peremptorily require, that every doctrine which claims the name of an explanation, shall be perfectly consistent with the acknowledged laws of mechanism; and that the explanation shall consist in pointing out those mechanical laws of which the facts in electricity are particular instances. It is no difficult matter to present an intricate or complex phenomenon to our view, in such a form that it shall have some resemblance to some other complex physical fact, more familiar, perhaps, but not better understood. The specious appearance of similarity, and the more familiar acquaintance with the other phenomenon, dispose us to consider the comparison as a sort of explanation, or, at least, an illustration, and to have a sort of indolent acquiescence in it as a theory.

But this will not do in the present question: For we have here selected a particular circumstance, the observed motions occasioned by electricity, and called *attractions* and *repulsions*—a circumstance which admits of the most accurate examination and comparison with any explanation that is attempted. In such a case, a vague picture would speedily vanish into air, and prove to be nothing but figurative expressions.

Many philosophers, and among them some respectable mathematicians, have supported the doctrine of Du Fay, Symmer, Cigna, &c. who employ two fluids as agents in all electrical operations. It must be granted that there are some appearances, where the explanation by means of two fluids seems, at first sight, more palpable and easier conceived. But whenever we attempt to obtain *measures*, and to say what will be the precise kind and degree of the action, we find ourselves obliged to assign to the particles of those fluids actuating mechanical forces precisely equivalent to those assigned by Æpinus to his single fluid. Then we have to add some mysterious unexplained connections, both with each other and with the other particles of tangible matter. If we except Mr Prevost, in his *Essai sur les Forces Magnetiques et Electriques*, we do not recollect an author who has ventured to subject his system to strict examination, by pointing out to us the laws of action according to which he conceives the particles influence each other. We shall have a proper opportunity, in the article *MAGNETISM*, to give this author's theory the attention it really merits. We venture to say, that all the chemical theories of electricity labour under these inconveniences, and have acquired their influence merely from the inattention of their partisans

General reflections.

WE have now given a comparison of the hypothesis of Mr Æpinus with the chief facts observed in electricity, diversified by every circumstance that seemed likely to influence the result, or which is of importance to be known. We trust that the reader will agree with us in saying that the agreement is as complete as can be expected in a theory of this kind; and that the application not only seems to explain the phenomena, but is practically useful for directing us to the procedures which are likely to produce the effect we wish. Thus, should our physiological opinions suggest that copious transference of fluid is proper, our hypothesis points out the most effectual and the most convenient methods for producing it. We learn how to constipate the fluid in a quiescent state, or how to abstract as much of it as possible from any part of a patient; we can do this even in the internal parts of the body. We had once an opportunity of seeing what we thought the cure of a paralysis of the gullet. Electricity was tried, first in the way of sparks, and then small shocks taken across the trachea. These could not be tolerated by the patient. The surgeon wished to give a shock to the œsophagus without affecting the trachea. We recommended a leaden pistol bullet at the end of a strong wire, the whole dipped in melted sealing wax. This was introduced a little way, we think not more than three inches, into the gullet, which the palsy permitted. A very slight charge was given to it in a few seconds; and the first shock produced a convulsion in the muscle, and the second removed the disorder completely. Here the ball formed the inner, and the gullet the outer, coating of the Leyden phial.

Notwithstanding the flattering testimony given by the great conformity of this doctrine with the phenomena, we still choose to present it under the title of a hypothesis. We have never seen the electric fluid in a separate state; nor have we been able to say in what cases it abounds, or when it is deficient. After what we have seen in the late experiments of that philanthropic philosopher Count Rumford on the production of heat by friction, we think that we cannot be too cautious on what grounds we admit invisible agents to perform the operations of Nature. We think that all must acknowledge that those experiments tend very much

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The reality of an electric fluid is denied.

Requisites for a just theory.

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No advantage is gained by the hypothesis of two fluids.

The theory of Æpinus is only a hypothesis.

tisans to the laws of mechanical motion, and require, in order to reconcile them with those laws, the adoption of powers similar to Æpinus's attractions and repulsions. Slight resemblances to phenomena, which stand equally in need of explanation, have contented the partisans of such theories, and figurative language and metaphorical conceptions have taken place of precise discussion. It would be endless to examine them all.

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Hypothesis
of Professor
Ruffel.

The most specious of any that we know was publicly read in the university of Edinburgh by the late Mr James Ruffel, Professor of natural philosophy; a person of the most acute discernment, and an excellent reasoner. It was delivered to his pupils, not as a *theory*, but as a *conjecture*, founded on Lord Kames's theory of spontaneous evaporation, which had obtained a very general reception; a conjecture, said the Professor, founded on such resemblances as made a similarity of operation very probable, and was an incitement and direction to the philosopher to a proper train of experimental discussion. We say this on the authority of his pupils in the years 1767, 1768, and 1769, and of some notes in his own hand-writing now in our possession.

Mr Ruffel considered the electrical phenomena as the results of the action of a substance which may be called the *electrical fluid*, which is connected with bodies by attractive and repulsive forces acting at a distance, and diminishing as the distance increases.

Mr Ruffel speaks of the electric fluid as a compound of several others; and, particularly, as containing elementary fire, and deriving from it a great elasticity, or mutual repulsion of its particles. This, however, is different from the elasticity or mutual repulsion of the particles of air, because it acts at a distance; whereas the particles of air act only on the adjoining particles. By this constitution, bodies containing more electric fluid than the spaces around them repel each other.

The particles of this electric fluid attract the particles of other bodies with a force which diminishes by distance.

The characteristic ingredient of this fluid is *ELECTRICITY properly so called*. This is united with the elastic fluid by chemical affinity, which Mr Ruffel calls *electric attraction*, a term introduced into chemistry by Dr Cullen and Dr Black. This extends to all distances, but not precisely by the same law as the mutual repulsion of the particles of the other fluid, and in general, it represses the repulsions of that fluid while in this state of composition. This *electricity*, moreover, attracts the particles of other bodies, but with certain elections. Non-electric or conducting bodies are attracted by it at all distances, but electrics act on it only at very small and insensible distances. At such distances its particles also attract each other.

By this constitution, the compound electric fluid repels its own particles at all considerable distances, but attracts at very small distances. It attracts conducting bodies at all distances, but non-conductors only at very small distances. The phenomena of light and heat are considered as marks of partial decomposition, and as proofs of the presence of elementary fire in the compound: the smell peculiar to electricity, and the effect on the organ of taste, are proofs of decomposition and of the complex nature of the fluid.

Bodies (conductors) containing electric fluid, repel each other at considerable distances, but, if forced very near, attract each other. Electrics can contain it only

in consequence of the *electricity* in the compound. Part of this electricity must be attached to the surface in a non-elastic state; because when it is brought so near as to be attracted, its particles are within the spheres of each other's action, and this redoubled attraction overcomes the repulsion occasioned by its union with the other ingredient; and the electric fluid is partly decomposed, and the *electricity*, properly so called, adheres to the surface of the electric, as the water of damp air adheres to a cold pane of glass in our windows. Also, by this constitution, electric fluid may appear in two states; elastic, like air, when entire; and unelastic, like water, when partly decomposed by the attraction of electrics.

Electricity may be forced into this unelastic union by various means; by friction, which forces the electric fluid contained in the air into close contact, and thus occasions this decomposition of the fluid and the union of its *electricity* with the surface. This operation is compared by Mr Ruffel to the forcible wetting of some powders, such as lycoperdon, which cannot be wetted without some difficulty and mechanical compression; after which it adheres to water strongly. It may be thus united in some natural operations, as is observed in the melting and freezing of some substances in contact with electrics; and it may be thus forced into union by means of metallic coatings, into which the electric fluid is forced by an artful employment of its mutual repulsions. This operation is compared to the condensation of the moisture of damp air by a cold pane of the window; and the evacuation of the other side of the coated pane is compared to the evaporation of the moisture from the other side of the window, pane in consequence of the heat which must emerge from the condensed vapour. We find in the Professor's notes above-mentioned many such partial analogies, employed to shew the students that such things are seen in the operations of Nature, and that his conjecture merits attention.

The intelligent reader will see that the general results of this constitution of the electric fluid will tally pretty well with the ordinary electrical phenomena; and, accordingly, this *conjecture* was received with great satisfaction. We remember the being much pleased with it, as we heard it applied by Mr Ruffel's pupils, many of whom will recollect what is here put on record. But the attentive reader will also see, that all this intricate combination of different kinds of attraction and repulsion is nothing but mere accommodations, of hypothetical forces to the phenomena. How incomparably more beautiful is the simple hypothesis of Æpinus, which, without any such accommodations tallies so precisely with all the phenomena that have yet been observed? Here no distinction of action is necessary, and all the varieties are consequences of a circumstance perfectly agreeable to general laws; namely, that the internal structure of some substances may be such as obstructs the motion of the electric fluid through the pores—Nothing is more likely.

Several years after the death of the Scotch Professor in 1773, a theory very much resembling this of Mr de Luc. Hypothesis of Mr de Luc. This gentleman having long cultivated the study of meteorology with unwearied assiduity and great success, and

and having been so familiarly conversant with expansive fluids, and the affinities of their compounds, was disposed to see their operations in almost all the changes on the surface of this globe. Electricity was too busy an actor in our atmosphere to escape his particular notice. While the mechanical philosophers endeavoured to explain its effects by accelerating forces attracting and repelling, Mr de Luc endeavoured to explain them by means of the expansive properties of aeriform fluids and gases, and by their chemical affinities, compositions, and decompositions. He had formed to himself a peculiar opinion concerning the constitution of our atmosphere, and had explained the condensation of moisture, whether of steam or of damp aeriform fluids, in a way much more refined than the simple theory of Dr Hooke, *viz.* solution in air. He considers the compound of air and fire as the *carrier* of the water held in solution in damp air, and the fire as the general carrier of both the air and the moisture. Even *fire* is considered by him as a *vapour*, of which *light* is the *carrier*. When this damp air or steam is applied to a cold surface, such as that of a glass pane, it is decomposed. The water is attracted by the pane by chemical affinity, and attaches itself to the surface. The fire, thus set at liberty, acts on the pane in another way, producing the equilibrium of temperature, and the expansion of the pane. Acting in the same manner on the moisture which chanced to adhere to the other side, in a proportion suited to its temperature, it destroys their union, enters into chemical combination with the moisture, and fits it for uniting with the air on the other side, or carries it off. Having read Mr Volta's theory of *electric influences*, by which that philosopher was enabled to give a scientific narration and arrangement of the phenomena of the *electrophorus* newly invented by himself, and which is called an explanation of those phenomena, Mr de Luc imagined that he saw a close analogy between those *influences* on the plates of the *electrophorus* and the *hygroscopic* phenomena of the condensation and evaporation of moisture. In short, he was struck with the resemblance between the condensation of moisture on one side of a glass pane, and its evaporation from the other; and the accumulation of electric fluid on one side of a coated pane, and the abstraction of it from the other. Subsequent examination pointed out to him the same analogy between all other *hygroscopic* and *electric* phenomena.

He therefore immediately formed a similar opinion concerning the electric operations. It may be expressed briefly as follows :

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The electrical phenomena are the operations of an expansive substance, called the *electric fluid*. This consists of two parts: 1. *Electric matter*, which is the gravitating part of the compound; and *electric deserent fluid*, or *carrying fluid*, by which alone the electric matter seems to be carried from one body to another. The resemblance between the *hygroscopic* and *electric* phenomena are affirmed to be*.

* See *Idees sur la Meteorologie*, § 266. &c.

1. As watery vapour or steam is composed of fire, the deserent fluid, and water, the gravitating part, so *electric fluid* is composed of the *electric deserent fluid*, and *electric matter*.

2. As *vapours* are partly decomposed when too dense for their temperature, and then their *deserent fluid* becomes free, and shews itself as *fire*; so *electric fluid*

that is too dense is decomposed, and its *deserent fluid* manifests itself in the *phosphoric* and *fiery* phenomena of *electricity*.

3. As *fire* quits the *water of vapour*, to unite itself with a body less warm; so the *electric deserent* quits the *electric matter*, in part, to go to other bodies which have proportionally less of it.

In this analogy, however, there is a distinction. *Fire*, in quitting the *water in vapour*, remains actuated by nothing but its expansive force; remains free, and extends itself till the equilibrium of temperature is restored; but the *electric deserent*, when disengaged from *electric matter*, in order to restore its peculiar equilibrium, is actuated by *tendencies* to distinct bodies, and acts by this *tendency* in thus restoring the *electric equilibrium*; and it is only in consequence of this *tendency* that it quitted the *electric matter*. This *tendency* is then directed to some body in the vicinity.

4. As the *fire of vapour* pervades all bodies, to restore the *equilibrium of temperature*, depositing the *water*; so the *electric deserent* quits the *electric matter*, to restore the *electric equilibrium* in an instant, and for this purpose pervades all bodies, depositing on them the *electric matter* which it carried, but differently, according to their natures.

5. As *fire* and *water*, while composing *vapour*, retain their *tendencies* and *affinities* by which they produce the *hygroscopic* phenomena; so the ingredients of the *electric fluid*, even in their state of union, retain their *tendencies* and *affinities*, which produce the greatest part of the *electric phenomena*.

6. In particular, the *electric matter* retains its *tendencies* and *affinities*; and farther, the *electric affinities* are, like the *hygroscopic*, without any choice.

Here, however, there is a farther distinction. The affinities of *water* respect only *hygroscopic* substances; but those of *electric matter* respect all substances, and therefore respect the common atmospheric fluids.

7. When *fire* quits the *water of vapour*, to form the *equilibrium of temperature*, it remains in the place where *vapour* most abounds, but is partly *latent*, not exerting its powers; so in the restoration of the equilibrium of the *electric deserent* among neighbouring bodies, those which have proportionally most *electric matter* also retain most *deserent fluid*, but in a *latent* state.

8. As two masses of *vapour* may be in *expansive equilibrium* (which others call balancing each others elasticity), although the *vapours* contain very different proportions of *fire* and *water*; so two masses of *electric fluid* may be in *expansive equilibrium*, although one contains much more *electric matter* in the same bulk, provided that the *electric deserent* be also more copious.

The chief distinction that mingles with these analogies is, that the *affinity* of *water* to *hygroscopic* substances operates only in contact, whereas *electric matter* tends to distant bodies; and these distances are very different in regard to different bodies.

Such is the resemblance which has appeared so strong to Mr de Luc. It is evidently the same which furnished the conjecture to Mr Ruffel, and which he considered mechanically, in order to explain the phenomena of electric motions to students of mechanical philosophy. The only resemblance seems to us to appear in the condensation of moisture contained in damp air.

Mr de Luc, led by the habits of his former studies, attempts

attempts to explain every thing by the relations which were most familiar to him, *affinities* and *expansive forces*. Let us attend a little to the manner in which he explains one or two of the most general facts.

1. *The conditions of conductors and non-conductors.*

230. This distinction depends on the differences in the *tendency* to distant bodies: there are great differences in these distances according to the nature of the bodies; and from this arise great differences of phenomena, independent of insulation or non-insulation, which are only the sensible distinctions of these classes of bodies. *Electric matter* tends to *conductors* at great distances; but having reached them it does not adhere, and remains free to move round them, being dragged by the *deserent fluid*; but its tendency to *non-conductors* is only at small and insensible distances; and having come into contact, it adheres, and can no longer be dragged by the *deserent fluid*.

Hence the operation of *conductors* and *non-conductors*; and there is no other foundation for the notion of *idiotrics* and *non-idiotrics*, or *electrics* by communication. A part of a *non-conductor* takes as much *electric matter* as it can from the substance furnishing it; but cannot communicate it to another part, except very slowly; therefore, to communicate it to the whole surface, we must cover it with a conductor (Surely this is a distinction in the body, independent of the distance of mutual tendency!).

Hence, too, the property of *non-conductors* by which the electric fluid is *benumbed* (*engourdi*) or cramped; therefore we can accumulate a great deal in them; and it will remain long, being *benumbed*; and if it be determined to quit them at once, the current will be much more dense than when quitting an equal conducting surface.

Since *conductors* do not fix the *electric fluid*, it *must circulate round them*. It is urged to this motion by its *expansive power*, by which it would disperse from a body with inconceivable velocity, and perhaps the rapidity of its motion would decompose it, and cause some *light* to emerge; but it is at the same time impelled by its *tendency* to bodies. Thus, by these two forces, it runs to a *conducting body*, and must circulate round it as the planets do round the sun. In this circulation, if it come to any great projection, it cannot follow the outline, because so abrupt; it therefore flies off at all points and protuberances. It will be the more difficult to keep to an abrupt outline as the stratum in circulation is more copious or deeper, because a greater mass is with greater difficulty turned round a sharp angle. It is more inclined to escape if another body be near, and it immediately becomes a satellite to that body.

Thus all bodies get a share of electric fluid, circulating round conductors, and *benumbed* or *cramped* in *non-conductors*. Bodies of this last class receive their portion by the air as *hygroscopic substances* receive their water by the *fire*.

All the differences in the tendencies to bodies proceed from the *electric matter*. The *deserent fluid* follows other laws; namely, 1. Its tendency to all substances is greater than that of the *electric matter* to any one. 2. The tendency (and also that of the *electric matter*) is always from the body which contains most of it to that which contains least. 3. The body which contains

most of the one also contains most of the other. 4. The *deserent fluid* has a particular affinity (chemical) with the *electric matter*. 5. All these tendencies are lessened by an increase of distance. 6. The *electric matter*, when composing *electric fluid*, has more or less *expansive force* as it is united to more or less *deserent fluid*.

Explanation of Charged Plates.

Mr de Luc says (§ 286.), that his SYSTEM was suggested by Volta's *Theory of Electric Influences*. These (says he) had been pretty well generalised before, but with little improvement to the science, till Mr Volta discovered a circumstance which, in his opinion, connected by a general relation many phenomena which had formerly no observed relation to any thing. This was, that when a body electrified positively brings a neighbouring body communicating with the ground into the negative state, its own positive electricity is weakened while it remains in that neighbourhood, but is recovered when the other body is removed. "Such is the distinguishing law of Mr Volta's theory, which brings all the phenomena of electric influences under his theory, beginning with those of coated glass, which were formerly so obscure, because they were not referred to their true cause, &c.

"My SYSTEM (Mr de Luc says) concerning the nature of the *electric fluid* explains the laws of Mr Volta's theory; and of consequence explains, like it, all the phenomena which it comprehends: but it reaches much farther, seeing that more general laws comprehend a greater number of phenomena.

"In the phenomena of coated glass, I plainly saw one of the procedures of *watery vapour*. Suppose a glass pane, moistened on both sides, and having the temperature of the surrounding bodies. Suppose that warmer *vapour* comes to one side. It is condensed on the surface; that is, it is decomposed, the *water* adheres to the surface, and the *fire* penetrates the glass, heats it, and increases the evaporation from the other side, by entering into combination with the *water*, and carrying it off with it. More *vapour* is condensed on the side A; more *fire* reaches the side B, and carries off more *water*. But as this happens only because the *fire* also raises the *temperature* of the pane, it is evident that the condensation on the side A, and the evaporation from B, must gradually slacken, and the *maximum of accumulation* in A, and of evaporation from B, will take place when the temperature of the pane is the same with that of the hot *vapour*.

"The electrical phenomena of coated glass are perfectly similar. The *electric fluid* reaches the side A, is decomposed, and the *electric matter* is there *benumbed* and fixed. The *deserent fluid* penetrates the pane, and carries off the *electric matter* from the side B. This goes on, but slackens; and the maximum of accumulation and evacuation obtains when the side A has acquired the same intensity of electricity with the charging machine. More is accumulated in A than is abstracted from B; because B is farther from the source (he might have added, that part of the fire is expended in raising the temperature of the pane): but the accumulation is inactive, because the *electric matter* is *benumbed* and fixed. Though the *electric matter* is much diminished in B, yet the *electric fluid* in its coating has as much expansive force as that of the ground; because

because it has a surplus of deferent fluid. The absolute quantity of *electric matter* in both sides is somewhat augmented."

232. This explanation of the Leyden phial comprehends the whole of Mr de Luc's theory; and the constitution of the electric fluid, and its various affinities, expansive powers and tendencies, are all assigned to it in subterfuge to this explanation, or deduced from those phenomena. As the author, in all his writings, claims some superiority over other naturalists for more general and comprehensive views, and for more scrupulous attention to precision and measurement, and particularly for more solicitude that no natural agent be omitted that has any share in the procedure—he surely will not be offended, although we should state such difficulties and objections as occur to us in the consideration of this SYSTEM (as he chooses to call it) of electricity.

We wish that it had been expressed in the plain and precise language of mechanical and chemical science; for he reasons entirely from the nature of expansive forces, tendencies, and affinities. His language will appear to some readers, as it does to us, rather to express the conduct of intelligent beings, acting with choice, and for a purpose, than the laws of lifeless matter. His account would have been less agreeable, it is true, but more instructive, and less apt to be mistaken. Metaphorical language is seldom used without the risk of metaphorical conceptions; and the reader is very apt to think that he has acquired a notion of the subject, while he is really thinking of a thing of a different nature. We apprehend that a great deal of this happens in this instance, and that when the narration is stripped of its figurative language, it will be found without that connection and analogy which it seems to possess.

We also wish that the explanation had been derived from some well-established principle. The whole of it is *professedly* founded on a resemblance between the phenomena of electricity, and some things said of watery vapour; but these are not the phenomena of watery vapour, but Mr de Luc's *hypothesis* (he will pardon us the term, which we prefer to *system*) concerning *watery vapours*. We do not think it philosophical to explain one hypothesis by another. Our illustrious countrymen, Bacon and Newton, disapproved of this practice; and their rules of philosophizing have still currency among philosophers. Explanation, in our opinion, is the pointing out some acknowledged general fact in nature, and shewing that the particular phenomenon is an example of it. We do not see this in Mr de Luc's explanation; because we do not see the *facts* in the case of watery vapours to which the phenomena of electricity are said to have a resemblance. The phenomena we mean are chiefly the *motions*, and the *transferences* of the powers producing such motions; we do not speak of the *light*, and some other phenomena, because Mr de Luc does not speak of them in this explanation. We shall even admit the *transference* as a *phenomenon*, although we do not see any substance transferred: but we see a power of producing certain motions where that power did not formerly appear; and the appearance of this power is all the authority adduced, even by Mr de Luc, for the transference. We must

now add, that the electric phenomena, which Mr de Luc calls like the phenomena of watery vapour, are all *suppositions*; and that therefore the explanation is a system of suppositions, framed so as to be like the system of watery vapour. For Mr de Luc will grant, that, on the one hand, we see nothing like the water in the electric phenomena; and, on the other hand, there is nothing in watery vapour like the motions of the electrometers, which are the only PHENOMENA from which Mr de Luc professes to reason.

We also fear that the very curious experiments of Count Rumford on the melting of ice, and the propagation of heat through liquids, will oblige Mr de Luc to change the tasks of the ingredients, both of *vapour* and of *electric fluid*. *Water*, and not *fire*, seems to be the *carrier* or *deferent fluid*; and we think that Franklin and Æpinus have made it highly probable that electricity, and not air, is the carrier.

We have also great difficulty in conceiving (indeed we cannot conceive) how the *deferent fluid*, from which the *electric matter* has been detached by its superior affinity with the side A, can overcome the *same superior affinity* of the *electric matter* with the side B (A), and carry it off; how the *deferent fluid* penetrates the non-conducting pane, in order to carry off the *electric matter* in the form of *fluid*; and how it cannot do this, except by means of a *conducting canal*, into which it is *expressly said that it does not penetrate*. It must not be said that it runs along the surface of this canal: for the smallest wire will be a sufficient conductor, covered a foot thick with sealing wax. This indeed, according to Mr de Luc, allows the *deferent fluid* to pass; but it must also, according to him, strain it pretty clear of all *electric matter*. For we cannot help thinking, that the process (although purely ideal) has a closer resemblance to what we should observe in a stream of muddy water poured on a strainer, both sides of which are previously foul. If we were disposed to amuse ourselves with a figurative hypothesis, we could give one on the principle of filtration that is very pretty, and pat to the purpose, of glass coated, and charged and discharged by conducting canals.

With respect to the suggestion of this theory by Volta's theory of electric influences, and the ignorance of naturalists before that time of the true state of things, we must observe, that Mr Ruffel proposed the same analogy to the consideration of his hearers many years before; and it was very generally known. The electric influences had been fully detailed by Æpinus and Wilcke in 1759, and applied with peculiar address and force of evidence by Mr Cavendish before 1771; and they were described nearly in the same way by Lane, Lichtenberg, and others.

And with respect to Mr Volta's general principle, which Mr de Luc prizes so highly, and by which he explains every thing, we must observe, that *it is not true as a phenomenon in electricity*; but, on the contrary, *the positive state of a body is rendered stronger, or more remarkable, by inducing the negative state on a neighbouring body*. See n^o 52. and 66.—Mr Volta was misled by the appearances of the electrophorus, which had engaged all his attention, and modelled all his notions on these subjects.

His:

(A) We may here ask, How comes there to be such a quantity of electric matter already lodged in B?—Is it benumbed? or in what state is it?

His observations had been confined to disks; and though these are excellent instruments for producing very sensible effects, they are quite unfit for examining the general nature of electric influences. Even without much knowledge of dynamics, a person must perceive that the action of their different parts on the electrometer may be very different, by reason of their different positions and distances from it. Besides, the electrometers of the apparatus described by Mr de Luc in sect. 440. &c. did not indicate the real condition of the disks to which they were attached, but the condition of the remote ends of overcharged conductors of considerable length. Therefore, although all the electrometers fell lower when the other group of disks was brought near, the positive state of the nearest disk was greatly augmented. The most unexceptionable apparatus for this purpose would be a row of polished balls on insulating stands, placed in contact, the whole charged positive; and when another such group, or a long body, is brought near, let the balls be separated at once, and examined apart by a very small electrometer, made in the form of our figure 8. We presume to say that, if the other group is properly managed, and made to communicate thoroughly with the ground, the positive electricity of the balls nearest to it will be found greatly augmented, and that every one of them will be found in that precise state of electrification that is pointed out by the Æpian theory. Mr de Luc has made and narrated the experiments with the disks, and the curious figures observed by Lichtenbergh, with great judgment and fidelity; and they are classical and valuable experiments for the examination of the theory. We may here mention a very neat way of executing the apparatus of balls, which was practised by a young friend, who was so kind as to make the experiments for us, when our thoughts were turned to Mr de Luc's theory. Each ball was mounted on a slender glass rod varnished. The lower end of the stalk was fixed in a little block of wood which had a square hole through it, by which it slid steadily along a horizontal bar of mahogany, supported at the ends about an inch from the table. The balls were made to separate at once, and equally, from each other, by a chequer-jointed frame, such as is seen in the toyshops, carrying a company of foot soldiers, who open and close their ranks and files by pulling or pushing the ends of the frame. Taking out the pins of the middle joints of this chequered frame-work, and widening the holes for receiving the glass stalks, it is plain that all the balls will separate at once, in the very state of electricity in which they were when in the neighbourhood of the non-insulated group. This apparatus consisted of six balls. We found the ball next the other group much more strongly positive than before bringing that group near; and it was generally the third ball which seemed equally electric in both situations. We added nine balls more, connecting the whole by a similar contrivance; and found it a most instructive apparatus for the theory of the distribution of the electric fluid. We wish that it had occurred to us when the n° 62, &c. were under consideration.

With respect to the condition in which the electric matter is said to be lodged in the side A of the coated pane, where Mr de Luc says that it is fixed, *engourdi*, in the *non-conducting surface* (which condition Mr de Luc considers as characteristic of such substances), we must

say that the description of its state is by no means agreeable to what we have observed. The powers of this *electric matter* are no more *benumbed* or *enervated* (it is a very unphilosophical phrase), than if it were in a *conducting* body at the same distance from the opposite coating. If coatings be applied to a block of glass of two or three inches in thickness, and if the electrification be so moderate that it would not fly from the one coating to the other when the glass is removed—no sensible difference will be found between the electricity of the two coatings with or without the glass. The electric matter in the side A has not its powers *engourdi*; they are *balanced* by the powers of the side B.

But how will Mr de Luc explain the charging a pane negatively? How will he bring off a quantity of *electric matter*, greater (according to his own account) than what will be *benumbed* on the other side? Nay, we must ask, where does he find it? Is there a quantity already *benumbed* there? What is to revive it?

Let us now consider a little the constitution of the ingredients of this electric fluid, by which all these things are brought about. And in doing this, let us banish, when possible, all figurative language; and, in the precise and dry phraseology of dynamics, let us speak of the motion of single particles of the *electric fluid*, *deserent fluid*, and *electric matter*. By *expansive power*, must certainly be meant such a power as that by which air, gases, inflamed gunpowder, steam, and the like, enlarge their bulk, and which is clearly manifested as a mechanical pressure, by bursting vessels, impelling bullets or pistons, &c. as well as by the actual enlargement of the bulk of the fluid. We have no other indications of its being a *force*; and therefore our notions of its mode of acting must be derived solely from what we *understand* of this power in air or the other fluids. Newton's *Principia* are our authority for saying that all that we know of it is, that it acts as a number of corpuseles would act, which repel each other with a force inversely proportional to their distances; this action not extending beyond the adjoining corpusele, not even to the second. We know a good deal of the propagation of pressure and progressive motion through such a fluid, when it is confined in a vessel, or system of vessels, of any form, and some few simple circumstances which take place in the elastic undulations which may be excited and propagated through it. We have but a *very indistinct notion* of the motions which one mass of such a fluid will produce in another mass, when both are at liberty to expand. This is very indistinct; but we are certain that it will be like the motion of two masses of air blown or driven against each other. Now these electric fluids, by their expansive powers, must act like those others with which we are more familiarly acquainted. And here we venture to say, that the appearances in electricity are so far from being like these, that we cannot imagine any thing more remarkably different. We shall mention but one thing. Every mark that we have for the presence of *electric fluid* obliges us to grant, that in an overcharged body it is crowded in to the external surface, so that the quantity has little or no relation to the quantity of matter in any body, but merely to its surface. This is quite unlike air, or any other expansive fluid, which is uniformly distributed through the whole space comprehended by the surface which bounds it. We never saw any thing like

like streams of this *electric fluid*, impelling or any way acting on each other, except in the transference by sparks; and there it was indeed like the motions of air, for it was not *electric fluid*, nor *electric matter*, but *electrified air*.

Let us next consider the *tendencies* by which the relations of these expansive fluids to other bodies are produced, and the electric motions are said to be explained. We observe that Mr de Luc avoids the use of the words *attraction* and *repulsion*, so much employed by the British philosophers. He considers these tendencies as determinate impulsions, and adopts the doctrine of *Le Sage of Geneva*, who has not only laid Newton under great obligations, by a mechanical explanation of gravity, but has also explained expansion, elasticity, chemical affinity, and all specific tendencies, to the satisfaction of the most eminent mathematicians. To such only Mr de Luc professes to address himself, who are not contented with a doctrine which supposes bodies to act where they are not. But, unfortunately, Mr le Sage has never obliged the world with this explanation. We are not most eminent mathematicians; but we are able to prove, that Mr le Sage's favourite theorem, mentioned by Mr de Luc in § 157, 158, as demonstrated by Mr Prevost, the editor of *Lucrece Newtonien*, is a complete dereliction of the first principles of Mr le Sage, and is also incompatible with mechanical laws. Mr de Luc should have given a demonstration of the theorem on which all his system rested; otherwise it is only reviving "*dixit philosophus, ergo verum.*"

But let us see what these tendencies perform. Mr de Luc says, that the fluid, setting out from a body by its expansive power, would move in a straight line with inconceivable velocity, and would immediately desert even this globe, were it not deflected by its tendency to other bodies. We do not see whence this immense velocity is derived. But let it go off; it is deflected from its rectilinear course by its tendency to some conducting body, which it reaches, but cannot, nor does not enter; and therefore *must continually circulate round it, as the planets circulate round the sun*, following its outline, if not too abrupt, but flying off from all points in the direction of the axis of the point, &c. Here we are at home; for this is a plain dynamical problem of central forces. All that we shall say on this head is, that Mr de Luc has certainly not considered the planetary motions with attention, when he hazarded this very comprehensive proposition. If he will take the trouble to do this, he will see that every part of it is inconsistent with the acknowledged laws of mechanism, and that the motions are absolutely impossible. Besides, we know that it will not fly off from a hundred points placed together, which is a still more abrupt line, if they do not project beyond the brim of a pit in which they stand; yet this pit only makes the outline more abrupt. We farther believe, that no person can form to himself any distinct notion of such circulations round every conducting body; they will be more numerous, and infinitely more confused and jarring, than all the vortices of Des Cartes. How can such motions take place round a bunch of brass wire buried in sealing wax? Yet he must grant that they really happen there; or what prevents the *electric fluid* from being *strained* clear of all electric matter in passing through the air?

We would also ask, why the tendency is always *from the body containing most of the fluid to that containing least?*

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It is not enough to say that it is so: this would only be contriving a thing to suit a purpose; a reason should be given if we pretend to explain. Now the tendency to a distant body *is to the matter* in that body, without any relation to the fluid in it, or in the body from which it came.

On the whole, we cannot think this theory is any thing but telling a story of ideal beings, in very figurative language, which gives it some animation and interest. The different affinities, tendencies, and powers, are only ways of expressing certain *supposed* events, and suited to those events: but it gives no explanation of the *observed mechanical phenomena* of electricity, shewing from acknowledged principles that they must be so.

What a difference between this laboured and intricate mechanism, and the simple, perspicuous, and distinct theory of Æpinus! Even Mr Ruffel's explanation is more intelligible, and more applicable to the *motions* which are really observed. That gentleman saw the necessity of considering them as the subjects of *mechanical discussion*, and that all that was wanted was to find out what law of distant action would tally with the phenomena. The Scotch philosopher was careful to warn his hearers that he only proposed a *conjecture*. The Swede calls his performance *Tentamen Theoriæ*, &c. and begins and concludes it with expressly saying, that it is only a *hypothesis*. The English nobleman calls his dissertation an *Attempt* to explain some of the phenomena, &c. None of these philosophers call their works a *SYSTEM*, which comprehends all theories, whether that of Volta or of any other successful inquirer.

We hope to be excused for treating so largely of this subject. It struck us as a very proper example of the bad consequences of indulging in figurative language. It must be very seducing, when so scrupulous and so eminent a philosopher as Mr de Luc is led astray by it.

We conclude this long article by observing, that whatever may be the fate of Mr Æpinus's *hypothetical theory*, his classification of the facts, and his precise determination of the *mechanical phenomena* to be expected from any proposed situation and condition of the substances, will ever remain, and be an unerring direction in future experiments; and the whole is an illustrious specimen of ingenuity, address, and good reasoning. We hope to make this still more evident, when we apply it to the quiet and manageable phenomena of MAGNETISM

233.

Pondere et mensurâ.

APPENDIX;

CONTAINING AN ABSTRACT OF MR COULOMB'S EXPERIMENTS.

MR COULOMB in the *Mem. de l'Acad. de Paris* for 1786, relates several experiments made for ascertaining the disposition or distribution of the electric fluid in an overcharged body. Their general results were,

1. That the fluid is distributed among bodies according to their figure, without any elective affinity to any kind of substance.

For when a ball, or body of conducting matter, and of any shape, is electrified to any particular degree, as indicated

indicated by his electrometer, if it be touched by another equal and similar body, similarly situated in respect of the touching points, the electricity is always reduced to $\frac{1}{2}$.

2. In an overcharged conducting body, the fluid diffuses itself entirely along the surface, without penetrating into the interior parts.

The conducting body AB (fig. 37.) had pits *a*, *b*, &c. made in various parts of its surface. They were half an inch in diameter, and some of them $\frac{1}{16}$ th, others $\frac{1}{8}$ ths, others $\frac{1}{4}$ th, &c. in depth. *c* represents the edge of a small circle of gilt paper, $\frac{1}{8}$ th of an inch in diameter, fixed perpendicularly on the end of a fine thread of gum lac. The body was electrified and touched with this little electroscope, by setting it flat down on the surface. The circle *c* was then presented to an electrometer which moved 90 degrees by a force not exceeding $\frac{1}{80000}$ th of a French grain. When this contact was made with the even surface of the conductor, it was strongly electrified, and particularly when it touched any eminence, or the ends of long cylinders, &c. The paper being exceedingly thin, and placed in full contact, it may be supposed to bring off with it the quantity of fluid corresponding to that part of the surface, or rather a greater quantity. But when it was made to touch the bottom, even of the shallowest of these pits, it did not affect the electrometer in the least.

He demonstrates the following elementary theorem :

The attraction or repulsion being supposed to be proportional to the inverse of any power *m* of the distance; that is, being as $\frac{1}{x^m}$: if *m* be greater than 3, the action of all the masses of fluid which are at a finite distance is nothing in comparison with the action in contact ; and therefore the fluid must be uniformly diffused, in the same way as if each particle acted only on the adjoining particles.

But if *m* be less than 3, for example, if *m* be 2, as seems to be the case in electricity, the action of all the masses at a finite distance is not infinitely small in comparison with the action in contact, and the redundant fluid must go toward the surface, and no redundant fluid will be retained in the interior parts. The demonstration is to this effect.

Let *A a B F* (fig. 38.) be a perfectly conducting body of any shape, and let *d a e* be a thin slice separated from the rest by the plane *d e* ; let *d c e* be precisely equal and similar to *d a e*, and let *a b c* be perpendicular to the separating plane ; then the action of all the particles in the thin slice *d a e* (when estimated in the direction *a b*) on the particle *b*, must balance the action of all the rest of the fluid in the body ; for *b* is supposed to be at rest. Now, as the law of continuity will be observed in any distribution of the fluid, through the whole body, it is plain that, by taking *a b* sufficiently small, the difference of density at *a* and at *c* may be infinitely small ; therefore the action of the fluid in *d a e* will be infinitely near to an equilibrium with the action of *d c e* ; and the action of the fluid in the rest of the body on the particle *b* will be infinitely small. This cannot be, when the action of a mass of fluid at a finite distance is not infinitely small in comparison with the action in contact, unless we suppose that the quantity of fluid at a finite distance is also infinitely small, or nothing ; that is, unless the whole redundant fluid is condensed on the surface, and the interior parts are merely saturated.

The preceding propositions are quite analogous to propositions in Mr Cavendish's dissertation in the Philosophical Transactions for 1771.

In the Memoirs of the same Academy for 1787, Mr Coulomb endeavours to ascertain the density of the fluid in different bodies which touch each other. When the bodies do not differ extremely in magnitude, he determines this by the immediate application of them to the electrometer ; but when one is extremely small in comparison with the other, he first determines the force of the large body, and then touches it 20 or 40 times with the small one, till the force of the large body is reduced to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c. The general result was, that when the surfaces of the spheres had the proportion expressed in the first column of the following Table, then the density in the small one had the proportion expressed by the numbers of the second column, and never attained the magnitude 2.

1	1
4	1,08
16	1,3
64	1,65
Infinite	2

This is extremely different from the proportions which obtain when the two spheres communicate by very long slender canals, which he found exactly conformable to the determinations of the theory : but in Mr Coulomb's experiments the spheres touched each other, and had no other communication.

He then endeavours to ascertain the density of the fluid in the different parts of the surface of these touching spheres, in order to obtain some experimental knowledge of the distribution. He touched them (while in mutual contact) with the little paper circle, and examined its electricity by his electrometer, and made his estimation on the supposition that it brought off one-half of the electricity of the touched part.

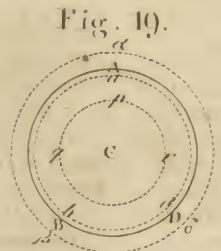
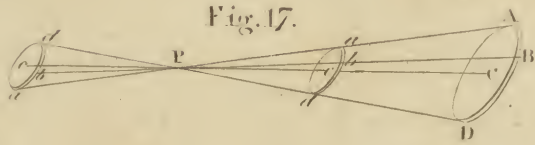
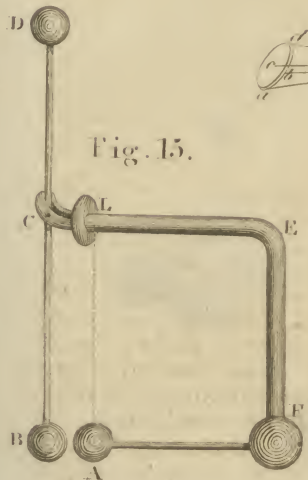
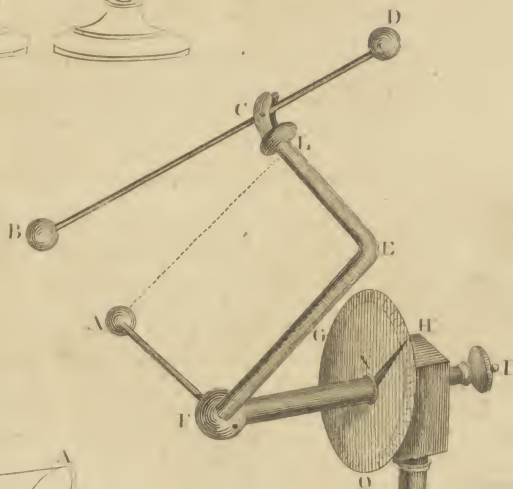
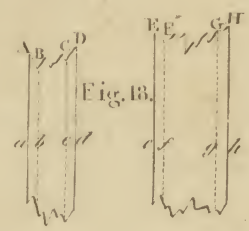
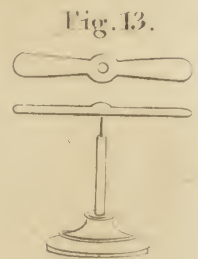
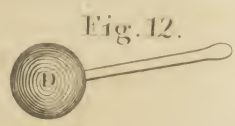
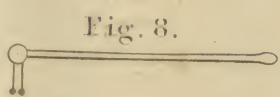
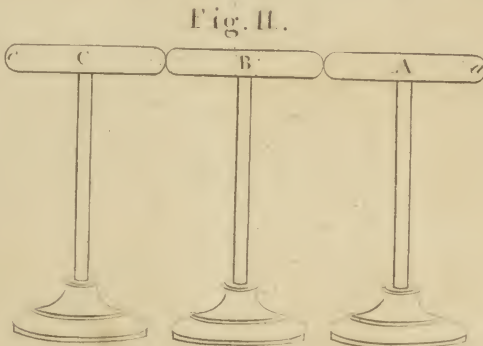
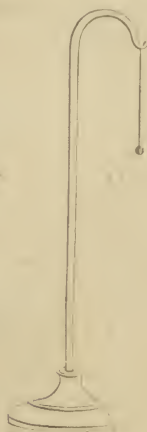
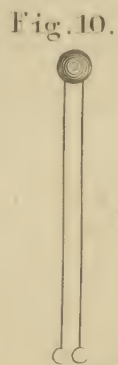
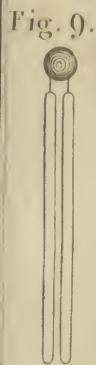
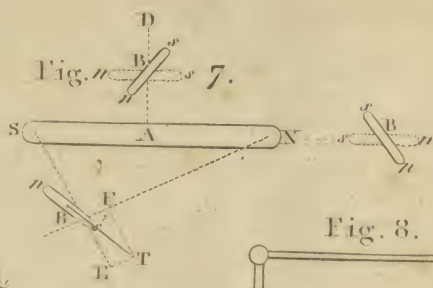
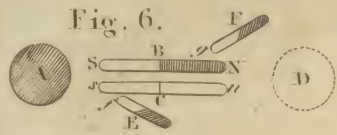
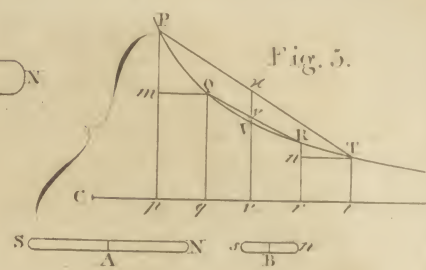
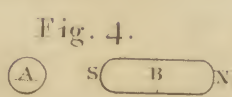
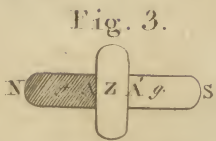
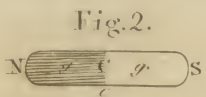
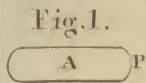
When the globes were equal, he found the density to be 0 in the point of contact, and scarcely sensible till he took the paper 30 degrees from the point of contact. From this it increased rapidly to 60° ; slowly from thence to 90° ; and from thence to 180° it was almost uniform. The densities were nearly

0	at	0°
1	—	30
4	—	60
5	—	90
6	—	180

He also found, that the more the globes differed in bulk, the more is the density changed in the small globe, and it is the more uniform in the great one, increasing rapidly from 0, at the point of contact, to about 7°, and beyond this being sensibly uniform.

Hence we may conclude, that the electricity is diffused with almost perfect uniformity in a globe communicating with another at a great distance by a slender canal (as Mr Cavendish has demonstrated) ; while, from the reasoning employed before, it is probable that it is also uniformly diffused all along the canal ; and therefore, that the quantities in two such globes are very nearly as the diameters, and the densities inversely as the diameters, as Mr Cavendish demonstrated, on the supposition that the fluid in the canal is incompressible.

He found that a small globe, placed between two equally large ones, shewed electricities of the same kind with that of the other two, when the radius of the



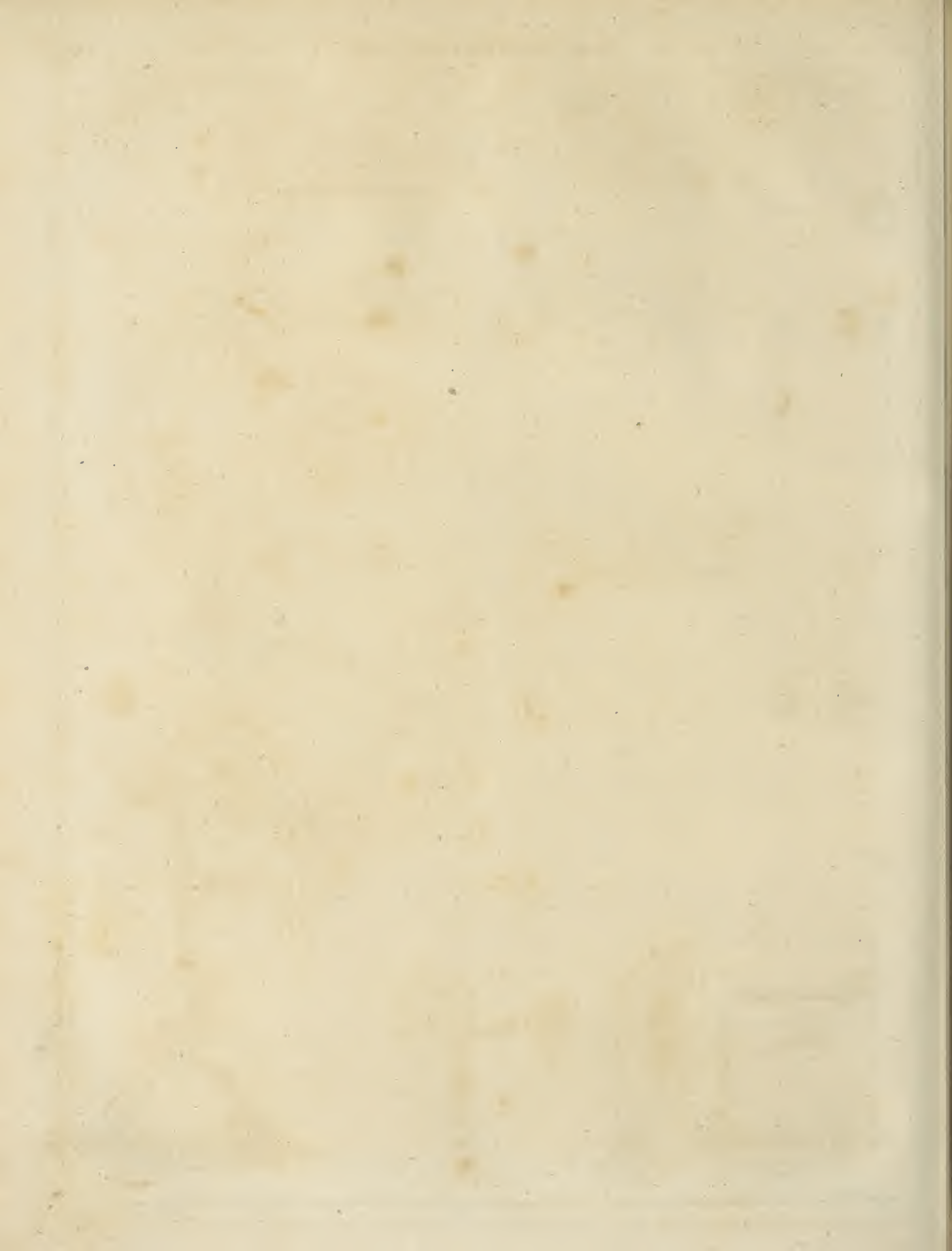


Fig. 20.

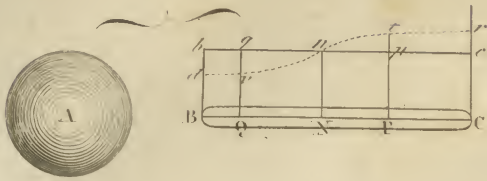


Fig. 24.

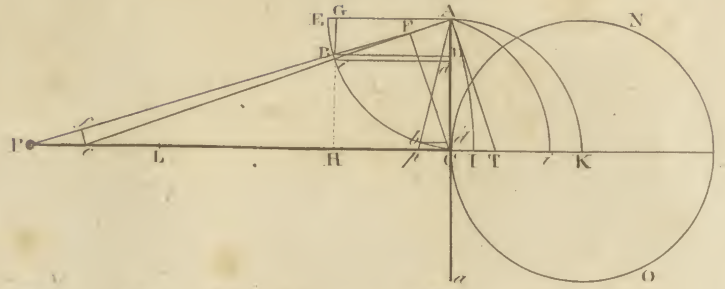


Fig. 21.

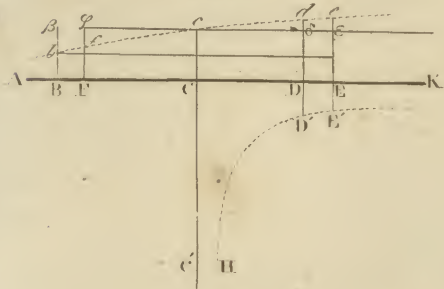


Fig. 22.

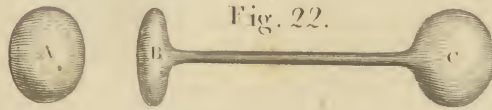


Fig. 23.

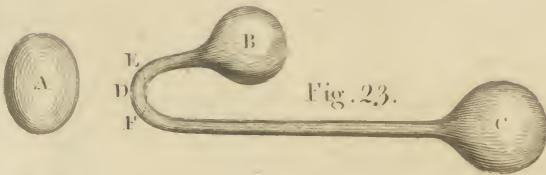


Fig. 25.

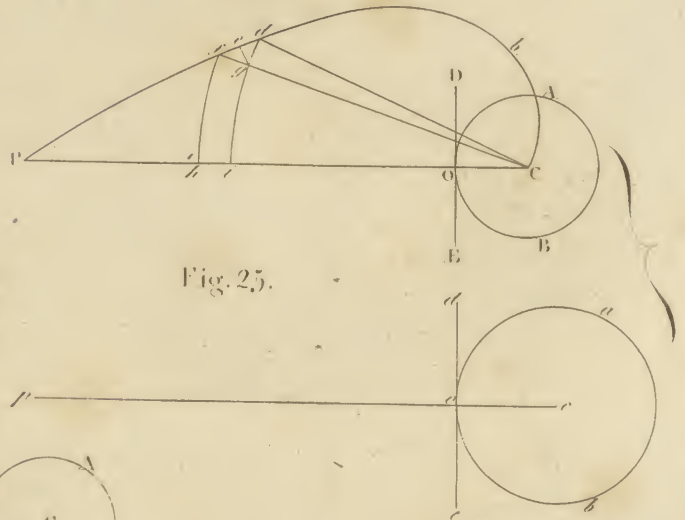


Fig. 26.

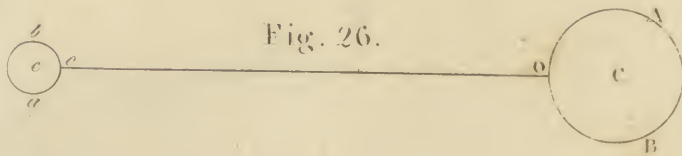


Fig. 27.

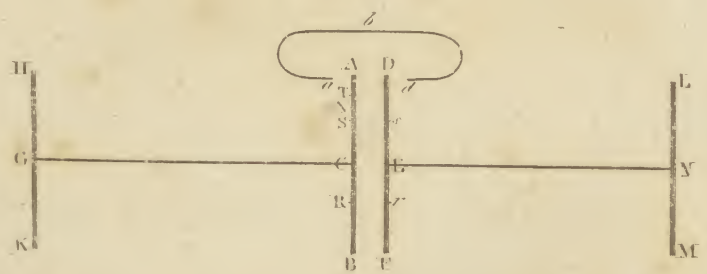
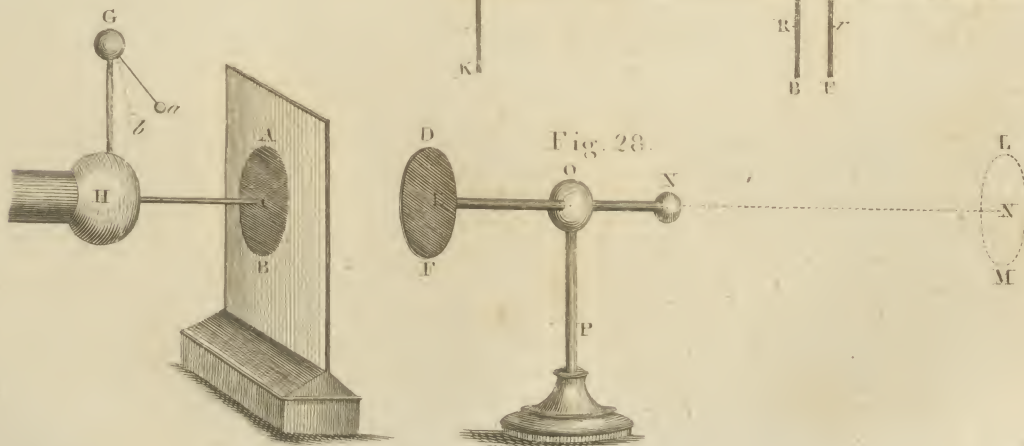


Fig. 28.



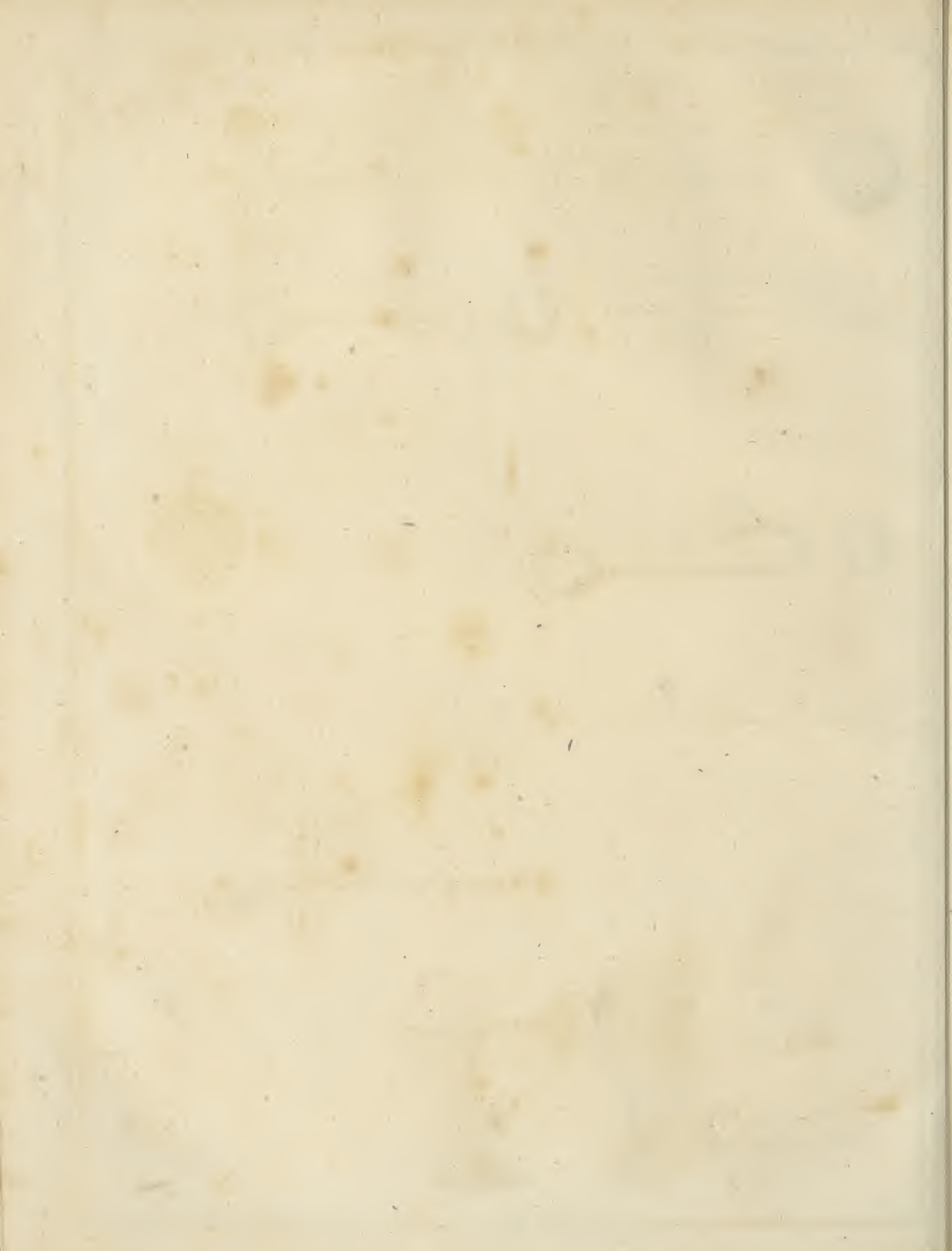


Fig. 29.

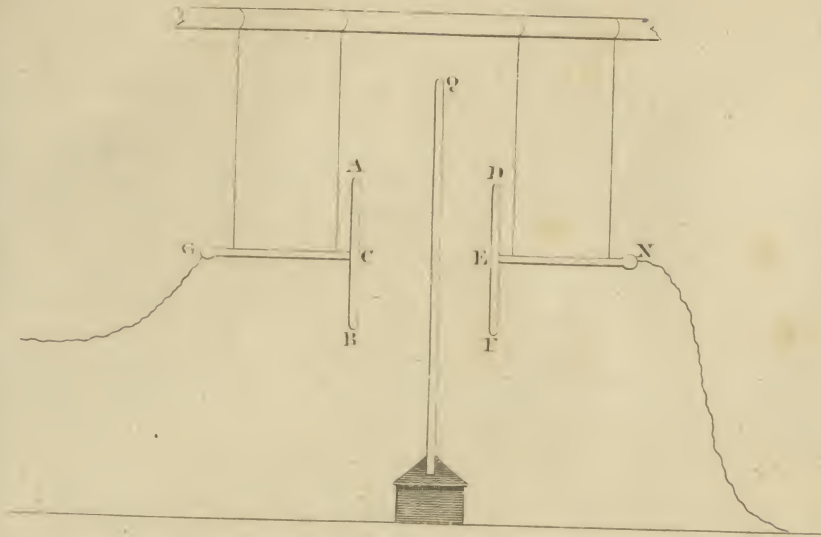


Fig. 30.

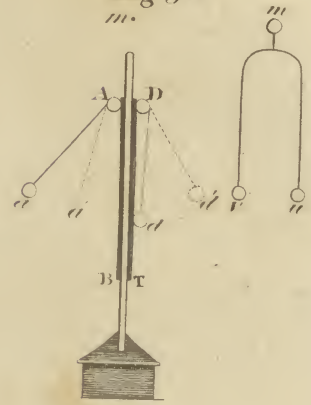


Fig. 31.

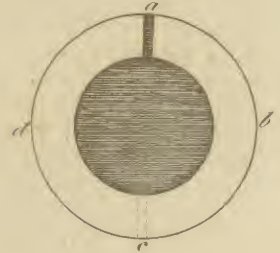


Fig. 32.

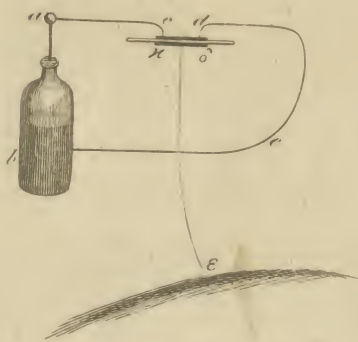


Fig. 34.

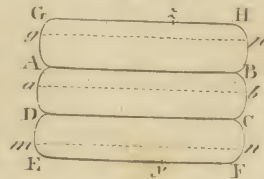


Fig. 35.

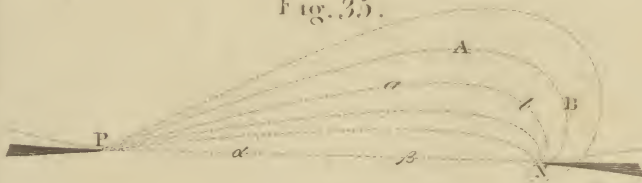


Fig. 33.

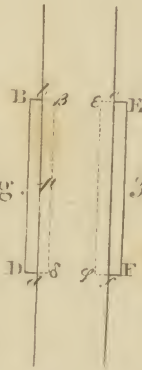


Fig. 36.

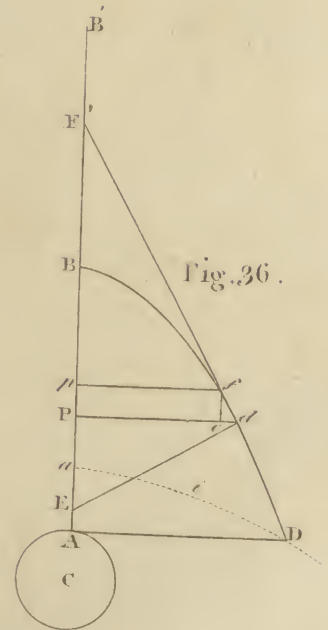


Fig. 37.

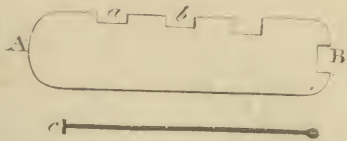
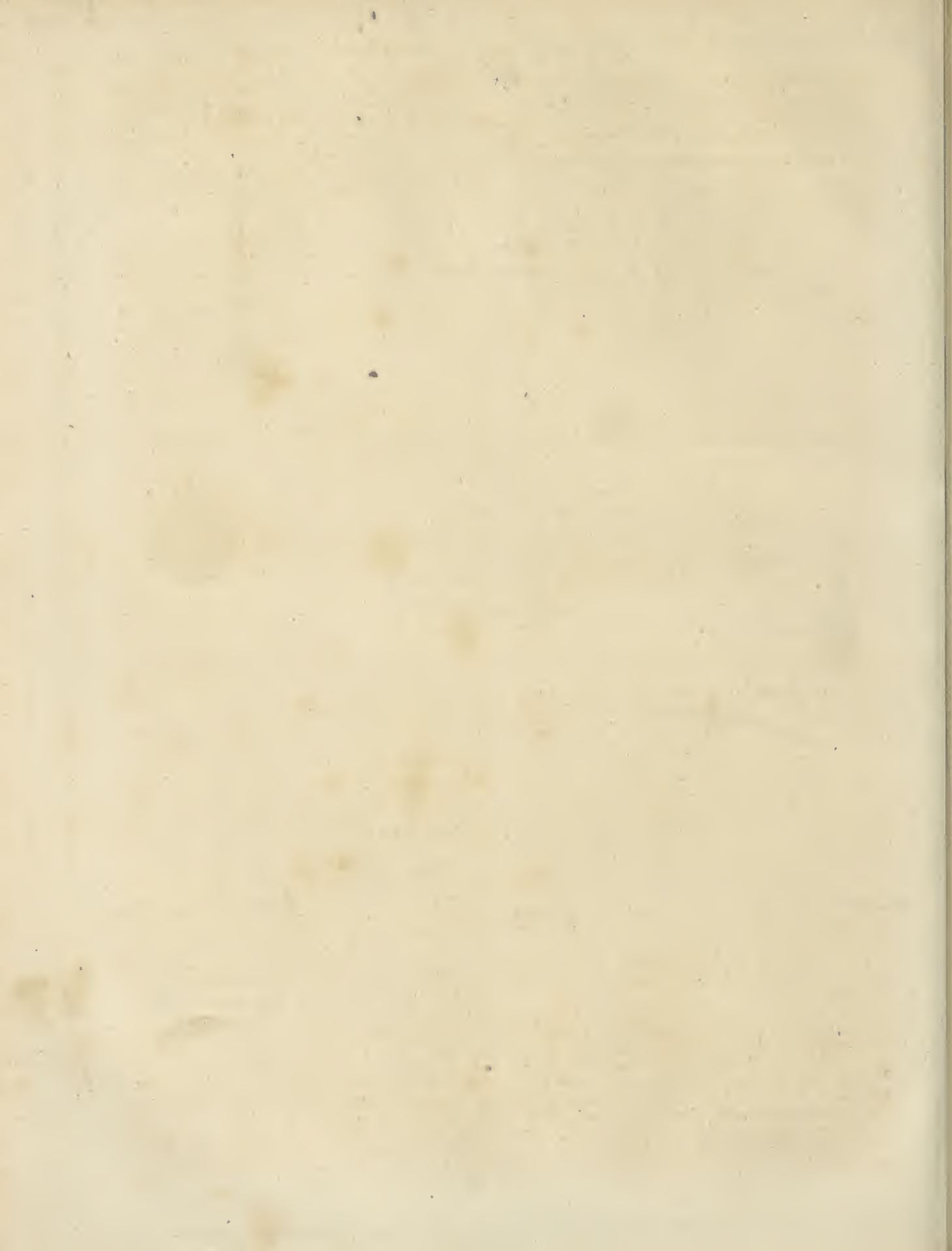


Fig. 38.





great one was not more than five times that of the middle one, but shewed no electricity when the disproportion was greater.

When three equal globes were in contact, the density of fluid in the middle globe was $\frac{1}{1,34}$ of that of the other two. A small globe being removed to a very small distance from an overcharged great one, *after having been in contact*, shewed opposite electricity in the fronting point; when a little farther off, it was neutral; and beyond this, it was overcharged.

The diameters being 11 and 8, the fronting point of the small one was negative till the distance was 1; here it was neutral, and when it was removed farther, it was positive. When the diameters were 11 and 4, the small globe was negative till their distance was 2, where it was neutral. When the diameters were 11 and 2, the distance which rendered the small globe neutral in the fronting point was $2\frac{1}{2}$.

All these facts are perfectly conformable to a mathematical deduction, from the supposition that the redundant fluid is spread over the surface, and that the interior points are neutral. If any sort of doubt should remain in the minds of those who are not conversant in such discussions, it must be greatly removed by the fact, that it is quite indifferent whether one or both globes be solid, or be an extremely thin shell.

When an electrified body is touched with a long wire, and by another of equal diameter and length, coated to any thickness with lac or sealing wax, the

two wires take off precisely the same quantity of electricity. This was demonstrated by touching a globe repeatedly till the electricity was reduced to $\frac{1}{4}$.

Hence we must conclude, that the electric fluid does not form active atmospheres around bodies, by the action of whose particles in contact (mathematical or physical) the phenomena of attraction and repulsion are produced, but by the action of the fluid in the body, agreeable to the theory of Æpinus.

Such are the observations of Mr Coulomb. They are extremely valuable, because they confirm in the completest manner the legitimate consequences of the theory.

We think that the materiality of that which is transferred from place to place in the exhibition of electric phenomena, is greatly confirmed by some observations of Mr Wilson's in the Pantheon. When a spark was taken from the whole of the long wire extended in that vast theatre, the sensation was so different from a spark which conveyed even a much greater quantity of fluid from a pretty large, but compact, surface, that they could hardly be compared. The last was like the abrupt twitch with the point of a hooked pin, as if pulling off a point of the skin; the spark from the long wire was more like the forcible piercing with a needle, not very sharp, breaking the skin, and pushing it inward. We had this account from the Doctor in conversation. He ascribed it, with seeming justice, to the momentum acquired by the fluid accelerated along that great extent of wire.

E L E

Electricity, *Animal ELECTRICITY.* See GALVANISM, in this Supplement.

ELECTROMETER, is an instrument which measures the quantity of electricity in any electrified body. The most common electrometers are described in the article ELECTRICITY (*Encycl.*), n° 27, and 182—233. A very valuable one is likewise described in n° 85. of the article ELECTRICITY in this volume; but there are still two electrometers, of which we have hitherto given no account, though they are of such value, that to pass them unnoticed would be unpardonable. The first, which is incomparably the most accurate and delicate instrument of the kind that we have seen, was invented by Mr Coulomb, and is adapted to ascertain the smallest quantity of redundant electricity. The second is a late invention of Mr Cuthbertson, the ingenious improver of the air-pump, and is employed only to measure the charge of large jars and batteries.

ELECTROMETER, by *Mr Coulomb* of the Royal Academy of Sciences at Paris, described in the Memoirs for 1785.

Mr Coulomb had made some experiments in examination of Dr Hook's theory of springs "*ut tensio sic vis*;" and found, that it was surprisingly exact, in regard to the force necessary for twisting elastic wires. Having suspended a nicely turned metal cylinder by a fine wire in the direction of its axis, and having given it several turns, and left it to regain its natural position, he observed, that it performed all its revolutions of untwisting and twisting in times precisely equal, whether these oscillations were of a few degrees, or consisted of

E L E

several revolutions. He thence concluded, that the force with which the wire endeavoured to regain its natural position was exactly proportional to its distance from it. Engaged, soon after, by order from the Minister of Marine, in an examination of the phenomena of the mariner's compass, he took this method of suspending his needles, in order to obtain exact measures of the forces which caused them to deviate from the magnetic meridian. He made some observations with needles so suspended; which are highly valuable to the philosopher engaged in that study. When his success in this research had fully gratified his wishes, he turned his thoughts to the examination of the law of electric action by the help of an electrometer suspended in the same manner. It is constructed as follows:

ABDC (fig. 1.) represents a glass cylinder, ¹²/_{Plate} inches in diameter and in height. This is covered by ^{XXVII.} a glass plate fitted to it by a projecting fillet on the under surface. This cover is pierced with two round holes of $1\frac{1}{2}$ th inches in diameter. One of them *f* is in the centre, and it receives the lower end of the glass tube *fb*, of 24 inches height, which is fixed in the hole with a cement made of sealing wax, or other electric substance. The top of this tube receives the brass collar *H* (fig. 2. n° 3.), bored truly cylindrical, and having a small shoulder, which rests on the top of the tube. This collar is fastened with cement, and receives the hollow cylinder *c* (fig. 2. n° 2.), to which is joined the circular plate *ab*, divided on the edge into 360 degrees. It is also pierced with a round hole *G* in the centre, which receives the cylindrical pin *i* (fig. 2. n° 1.), having

Electrometer.

a milled head *b*, and an index *i o*, whose point is bent down, so as to mark the divisions on the circle *a b*. This pin turns stiffly in the hole *G*, and the cylinder ϕ turns steadily in the collar *H*. To the lower end of the centre pin is fastened a little pincer *g*, formed like the end of a port-crayon, and tightened by the ring *g*, so as to hold fast the suspension wire, the lower end of which is grasped by a similar pincer *P o* (fig. 3.), tightened by the ring *p*. The lower end *o* is cylindrical, and it is of such weight as to strain the wire perfectly straight, but without any risk of breaking it. It may be made half of the weight that will just break it.

This pincer is enlarged at *C*, and pierced with a hole, which receives tightly the arm *g C g* of the electrometer. This is eight inches long, and consists of a dry silk thread, or slender straw of some grass completely dried, and dipped in melted gum lac or fine sealing wax, and held upright before a clear fire, till it form a slender cylinder of about $\frac{1}{10}$ th of an inch in diameter. This occupies six of the eight inches, from *g* to *g*: the remaining two inches is a fine thread of the lac or sealing wax, as it drains off in forming the arm. At *a* is a ball of pitch of elder or fine cork, one-fourth or one-half of an inch in diameter, made very smooth, and gilded. It is balanced by a vertical circle *g* of paper, of large dimensions, stiffened with varnish. The resistance of the air to this plane soon checks the oscillations of the arm.

The whole is seen in its place in fig. 1. where the arm hangs horizontally about the middle of the height of the great cylinder. In its oscillations the ball *a* moves round in a circle, whose centre is in the axis of the whole instrument. Its situation is indicated by a graduated circle *Z O Q*, drawn on a slip of paper, and adhering to the glass with varnish. The electrified body, whose action is to be observed, is another small ball of cork *t*, also gilt, or a brass ball well polished. This is carried by a stalk of gum lac *m p*, inclosing a dry silk thread. This stalk is grasped by a clamp of cleft deal, or any similar contrivance which lies firm on the glass cover. When this ball is let down through the hole *m*, it stands so as to touch the ball *a* on the arm when that ball is opposite *o* on the graduated circle.

To electrify the ball *t*, we employ the insulating handle, fig. 4. which is a slender stick of sealing wax or lac, holding a metal wire that carries a small polished metal ball. We touch with it some electrified body, such as the prime conductor of a machine, the knob of a jar, &c. Introduce this electrified ball cautiously into the hole *m*, and touch the ball *t* with it. The ball *a* is immediately repelled, and goes to a distance, twisting the suspension-wire, till the force of twist exerted by the wire balances the mutual repulsion of the balls *t* and *a*.

Such is the process for examining the law of electric action. But when we would examine the action of different bodies in different states, another apparatus is wanted. This is represented by the piece *c A d* (fig. 5.), consisting of a plug of sealing wax *A*, which fits tight into the hole *m*, and is pierced by the wire *c d*, hooked at *c*, to receive a wire connecting it occasionally with an electrified body, and having below a polished metal ball *d*.

The instrument is fitted for observation in the following manner: Turn the milled button *b* at top, till the twist-index *i o* is on the mark *o* of the twist circle. Then turn the whole in the collar *H*, till the ball *a* stands

opposite to the mark *o* of the paper circle *z O Q*, and at the same time touches the ball *t* or *d*.

Electrometer.

The observation is made thus: The ball *t* is electrified as already said, and *a* is repelled, and retires from *t*, twisting the wire, and, after a few oscillations, settles at a distance corresponding to the repulsion. Now turn the twist-index, so as to force the ball *a* nearer to *t*. We estimate the force of this new repulsion by adding the motion of the twist-index to the angle at which the ball first rested. By turning the twist-index still more, we bring the balls still nearer, and have a measure of another repulsion.—And thus may we obtain as many measures as we please.

In this way Coulomb ascertained the relation between the repulsion and the distance to be the inverse duplicate ratio of the distances. He discovered the law of dissipation by air in contact, and the relation which this bears to the primitive repulsion, by observing the gradual approach of *a* to *t* as the electricity dissipates from both, and by slackening the twist-index till the ball *a* retires to its primitive distance. He ascertained the dissipation along imperfect conductors and the length necessary for insulation, by completely insulating the ball *t*, and observing the loss by air in contact with it, and then sliding a metal rod down the insulating stalk, till the dissipation began to exceed what took place by the air alone. He examined the proportion of redundant fluid in communicating bodies, by connecting them alternately with the piece, fig. 5.; as also by electrifying one ball, and observing its repulsive force, and then sharing its electricity with another, and observing the diminution. He examined the graduation of his electrometer, by sharing the electricity of one ball with an equal ball, which gave him the position that indicated one-half; and, by repeating this, for one-fourth, &c. in the same manner as we practised and related in ELECTRICITY (*Suppl.*), n^o 141, &c.

An example of one or two of those trials will give a clear conception of the conclusions deduced from these observations.

The ball *t* was introduced and electrified; *a* was repelled, and settled at 40°; the index was twisted 140°, which brought *a* to 20; and the time was noted. The electricity gradually dissipated, and *a* came nearer to *t*. The index was untwisted 30°, and *a* retired a little beyond 20°; but on waiting a few seconds, it stood exactly at 20°. The time was again noted. The interval was exactly three minutes. The conclusion from the experiment was as follows:

When the ball was brought to 20°, the repulsion was evidently 140 + 20, or 160. Three minutes afterwards it was 210 + 20, or 130; and 30° were lost in three minutes, or 10° per minute. The mean force was 145. Therefore the mean loss per minute was $\frac{15}{145}$. Observe also, that the primitive force corresponding to the distance was 40; and the force corresponding to 20 was 160, or inversely as 20² to 40².

But observe, that the distances were not measured by the angles, but by the chord of the angles. The obliquity of action must also be accounted for; and the real lever is less than the arm, in the proportion of radius to the cosine of $\frac{1}{2}$ the angle.

The wire used by Coulomb in his first experiments on the law of action was of such strength, that $\frac{1}{15}$ th of a French grain, applied at the point *a*, held it fast

Electrometer. till the twist index was turned 360° ; so that one degree corresponded to $\frac{1}{12 \times 14 \times 100}$ of a grain. A foot of this wire weighed $\frac{1}{10}$ th of a grain. Experience having shewn that this was a sensibility far exceeding what was necessary for the measures that he had in view, and made the instrument too delicate for common uses, he substituted much stronger and shorter wires, and recommends much smaller dimensions for the whole instrument. We have made two of only five inches in diameter and 14 inches high; the arm *ag* being $2\frac{1}{4}$ inches, and the suspension a single fibre of silk, carrying 30 grains. It is far more sensible than Bennet's gold leaf electrometer. The same instrument, with a silver wire suspension, and a thread of lac projecting from the end *g*, as an index to coincide more closely with the scale, is sufficiently nice for all experiments of measurement. It is always proper to have the diameter of the cylinder double the length of the arm, that the action of the glass may not disturb the position of the arm. It is greatly improved by having a round hole in the bottom of the instrument, in which the cylinder *C* of the lower pincer may hang freely: this prevents much tedious oscillation. For ordinary experiments, for measuring charges of batteries, and the like, a much less delicate instrument, with a suspension-wire strained at both ends, is abundantly delicate, and vastly more manageable. The wire should extend as far below the arm as above it, and should be grasped below, by a pincer turning by a milled head in a hole at the end of a slender spring. This enables us to adjust the instrument speedily. Having placed the twist-index at *o*, turn this lower button gently till the ball *a* points exactly to *o* on the paper circle. Even in this coarsest state we have found it more delicate, and much more exact, than the electrometer described in *ELECTRICITY (Suppl.)*, no 85. which was much more costly, and liable to accidents. Coulomb's electrometer has the great advantage of wasting very little electricity; whereas Henley's, or Brookes's, or de Luc's, waste it very fast when it is intense.

We improved it greatly by taking away the apparatus with the ball *t*, and substituting the piece, fig. 5. for it, after changing its construction a little. Instead of the wire *cd*, we used the smallest glass tube that we could varnish on the inside, by drawing through it a silk thread dipped in varnish. Having varnished it with lac both within and without, a brass ball *d* was fixed on its lower end, and a fine wire, with a ball at top, was put down into the tube, so as to touch the ball below. When the plug was fitted into the hole *m* once for all, the situation of the ball *d* suffered no alteration. When delicate experiments are to be made, the upper ball *c* is touched by the charger, fig. 4. which electrifies *d*. *C* is immediately drawn out with a glass forceps; and thus *d* is left completely insulated. When external electricity, such as the faint electricity of the atmosphere is to be examined, the wire is allowed to remain in the tube.—*N. B.* A scrupulous experimenter, who may object to the straining spring recommended above, may substitute a small weight, which will be constant in its action.

The reader will observe, that this electrometer, as hitherto managed, measures only repulsions. It is not so easy to measure attractions with it; and Mr Coulomb was obliged to take a very circuitous method, during which a great deal of electricity was dissipated. In this respect, the electrometer described in the article

ELECTRICITY (Suppl.) has the advantage; but in every other respect, Mr Coulomb's is the finest electrometer that has yet been published, giving *absolute* measures, and this with great accuracy. The Hon. Mr Cavendish has employed the construction in his most valuable experiments on the force of gravity (*Phil. Transf.* 1798, Part II.); an experiment which Newton would have been delighted with observing.

Cuthbertson's ELECTROMETER is thus described by himself in the last number of the second volume of *Nicholson's Philosophical Journal*. GH (fig. 6.) is an oblong piece of wood, about 18 inches in length and six in breadth, in which are fixed three glass supporters, D, E, F, mounted with brass balls, *a, c, b*. Of these supporters E and F are exactly of the same length; but D is four inches shorter. Under the brass ball *a* is a long brass hook; the ball *c* is made of two hemispheres, the under one being fixed to the brass mounting, and the upper turned with a groove to shut upon it, so that it can be taken off at pleasure. The ball *b* has a brass tube fixed to it, about three inches long, cemented on the top of F, and the same ball has a hole at the top, of about one-half inch diameter, corresponding with the inside of the tube. AB is a straight brass wire, with a knife-edged centre in the middle, placed a little below the centre of gravity, and equally balanced with a hollow brass ball at each end, the centre, or axis, resting upon a proper shaped piece of brass fixed in the inside of the ball *c*; that side of the hemisphere towards *c* is cut open, to permit the end *c* A of the balance to descend till it touches the ball *a*, and the upper hemisphere C is also cut open to permit the end *c* B to ascend; *i* is a weight, weighing a certain number of grains, and made in the form of a pin with a broad head; the ball B has two holes, one at the top, and the other at the bottom; the upper hole is so wide, as to let the head of the pin pass through it, but to stop at the under one, with its shank hanging freely in *b*; *k* is a common Henley's quadrant electrometer; and when in use it is screwed upon the top of *c*.

It is evident, from the construction, that if the foot stand horizontal, and the ball B be made to touch *b*, it will remain in that position without the help of the weight *i*; and if it should by any means receive a very low charge of electric fluid, the two balls *b, B*, will repel each other; B will begin to ascend, and, on account of the centre of gravity being above the centre of motion, the ascension will continue till A rest upon *a*. If the balance be set again horizontal, and the pin *i* be put into its place in B, it will cause B to rest upon *b*, with a pressure equal to that weight, so that more electric fluid must be communicated than formerly before the balls will separate; and as the weight in B is increased or diminished, a greater or less quantity of electric fluid will be required to effect a separation.

When this instrument is to be applied to a jar, or battery, one end of a wire L must be inserted into a hole in *b*, and the other end into a hole of any ball proceeding from the inside of a battery, as M. A chain, or wire, or any body through which the charge is to pass, must be hung to the hook at *m*, and carried from thence to the outside of the battery, as is represented by the line N. *k* must be screwed upon *c*, with its index towards A. The reason of this instrument being added, is to shew, by the index continuing to rise, that the charge of the battery is increasing, because the other

Electrometer.

Electrometer
||
Elephas.

other part of the instrument does not act till the battery has received its required charge.

It is almost needless to observe that this instrument consists of three electrometers, viz. Henley's electrometer, Lane's discharging electrometer considerably improved, and Brookes's steelyard electrometer improved likewise. By this combination and these improvements, we possess all that can be required in an electrometer for batteries and large jars; for, by *k*, we see the progress of the charge; by the separation of *B b*, we have the repulsive power in weight; and by the ball *A*, the discharge is caused when the charge has acquired the strength proposed.

In the journal from which this abstract is taken, the reader will find some curious experiments made with batteries by means of this electrometer; but one will be sufficient to explain its use. Prepare the electrometer in the manner shewn in the figure, with the jar *M* annexed, which contains about 168 square inches of coating. Take out the pin in *B*, and observe whether the ball *B* will remain at rest upon *b*; if not, turn the adjusting screw at *C* till it just remains upon *A*. Put into *B* the pin, marked *i*, weighing 15 grains; take two inches of watch-pendulum wire, fix to each end a pair of spring tongs, as is represented at *G m*, hook one end to *m*, and the other to the wire *N*, communicating with the outside of the jar; let the uncoated part of the jar be made very clean and dry; and let the prime conductor of an electrical machine, or a wire proceeding from it, touch the wire *L*; then, if the machine be put in motion, the jar and electrometer will charge, as will be seen by the rising of the index of *k*; and when charged high enough, *B* will be repelled by *b*, and *A* will descend and discharge the jar through the wire which was confined in the tongs, and the wire will be fused and run into balls. The ingenious author, by breathing through a glass pipe into the jar, damped it a little in the inside. Then loading *B* with a pin of 30 grains, he obtained such a charge as fused eight inches of watch pendulum wire, disposed exactly as the two inches were disposed in the former experiment. By repeating and varying his experiments, he found that double quantities of electrical fluid, in the form of a discharge, will melt four times the length of wire of a certain diameter.

ELECTROPHORUS. See **ELECTRICITY** in this Supplement.

ELEPHAS, the **ELEPHANT**. See *Encyclopædia*; where the natural history of this huge and sagacious animal is detailed at considerable length. Since that article was published, we have seen the third volume of the Asiatic Researches, in which some important questions, which we were then obliged to leave in uncertainty, seem to be decided by John Corfe, Esq. They relate, 1st, To the mode in which elephants copulate; which Buffon asserts (and in proof of his assertion adduces the structure and position of the generative organ in the female) to be performed while that female remains recumbent on the back; but which Mr Corfe infers from ocular evidence, takes place after the manner in which the horse copulates with the mare. 2^d, To the method of receiving nourishment from the mother; which is not, as Buffon avers, by the trunk, but by the mouth, which sucks the dug, while the trunk of the young animal grasps it round to press out the milk. 3^d, To the period of their going with young; which

Mr Corfe conceives cannot be less than two years; whereas Bullon and Pennant assign only nine months for the gestation of their young. His reasons for this supposition are unanswerable, and shall be given in his own words.

“As far as I know, the exact time an elephant goes with young has not yet been ascertained; but it cannot be less than two years, as one of the elephants brought forth a young one, twenty one months and three days after she was taken. She was observed to be with young in April or May 1788, and she was only taken in January preceding; so that it is very likely she must have had connection with the male some months before she was secured, otherwise they could not have discovered that she was with young, as a foetus of less than six months cannot well be supposed to make any alteration in the size or shape of so large an animal. The young one, a male, was produced October 16, 1789, and appeared in every respect to have arrived at its full time. The gentleman to whom it belongs examined its mouth a few days after it was brought forth, and found that one of its grinders on each side had partly cut the gum.”

When Mr Corfe wrote his memoir, the young elephant was active and well, and beginning to eat a little grass. In Africa the Hottentots feed on the elephant; and M. Vailant declares, that an elephant's foot, when baked in their manner, is a most delicious morsel.

ELEPHANTIASIS (see **MEDICINE**, n^o 352. *Encycl.*) is one of the most dreadful maladies with which the human race is anywhere afflicted. It is not indeed common, if it be found at all, in the temperate climates of Europe; but it is frequent in the East and West Indies, where it too often baffles the skill of the ablest physicians. In the second volume of the Asiatic Researches we have the following prescription for its cure:

“Take of fine fresh white arsenic one t^ol^a, or 105 grains; of picked black pepper six times as much: let both be well beaten at intervals for four days successively in an iron mortar, and then reduced to an impalpable powder in one of stone with a stone pestle, and thus completely levigated, a little water being mixed with them. Make pills of them as large as tares or small pulse, and keep them dry in a shady place. One of those pills must be swallowed morning and evening with some betel leaf, or in countries where betel is not at hand, with cold water: if the body be cleansed from foulness and obstructions by gentle cathartics and bleeding before the medicine is administered, the remedy will be speedier.”

This prescription, we are told, is an old secret of the Hindoo physicians, which they consider as a powerful remedy against all corruptions of the blood, whether occasioned by the elephantiasis or the venereal disease, which they call the *Persian fire*, and which they apply likewise to the cure of cold and moist distempers, or palsy, distortions of the face, relaxation of the nerves, and similar diseases. As the Hindoos are an ingenious and scientific people, it might be worth some European physician's while to make trial of this ancient medicine in the West Indies, where the elephantiasis or kindred diseases prove so frequently fatal.

ELEVATION, in architecture, denotes a draught or description of the principal face or side of a building; called also its *upright* or *orthography*.

ELLIPSE, or **ELLIPSIS**, is one of the conic sections,

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Ellipsc.

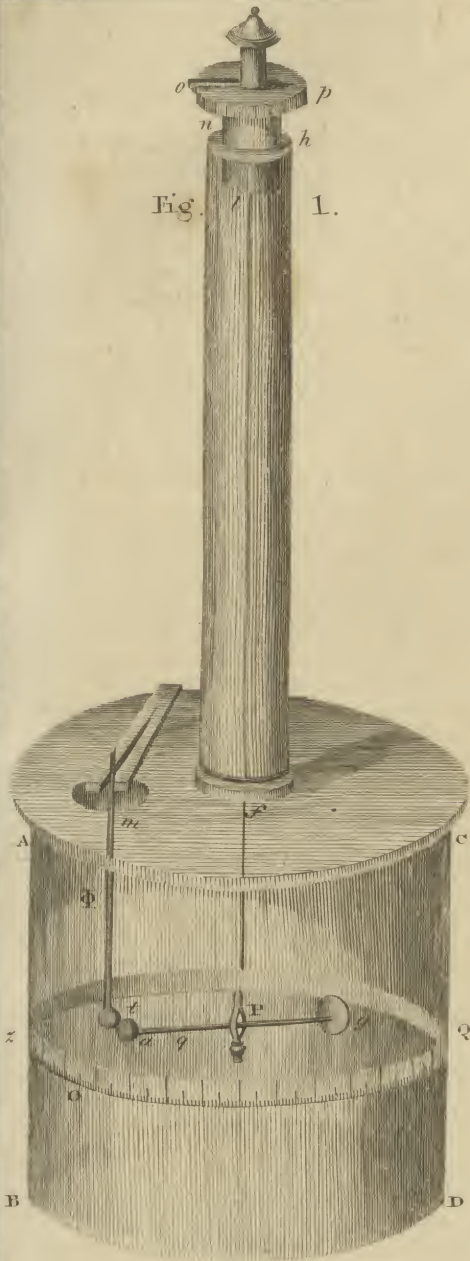


Fig. 1.

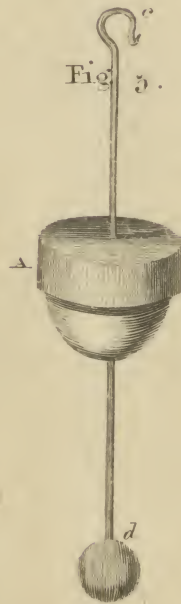


Fig. 2.

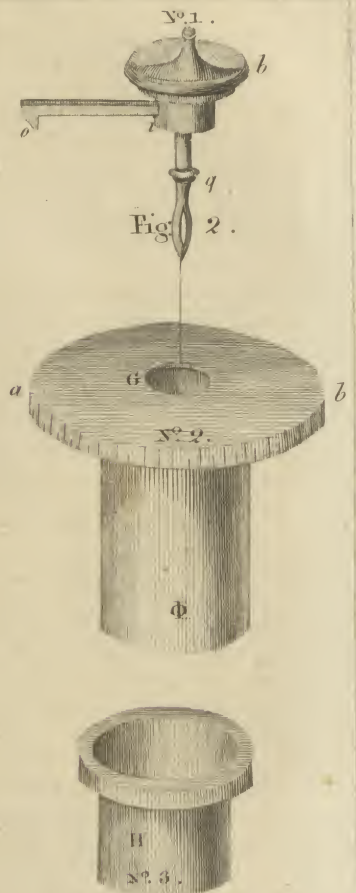


Fig. 3.

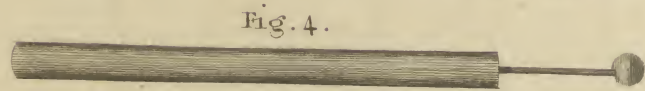


Fig. 4.

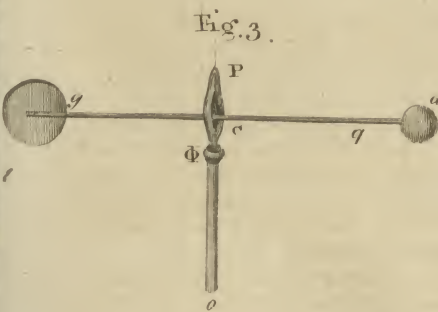


Fig. 5.

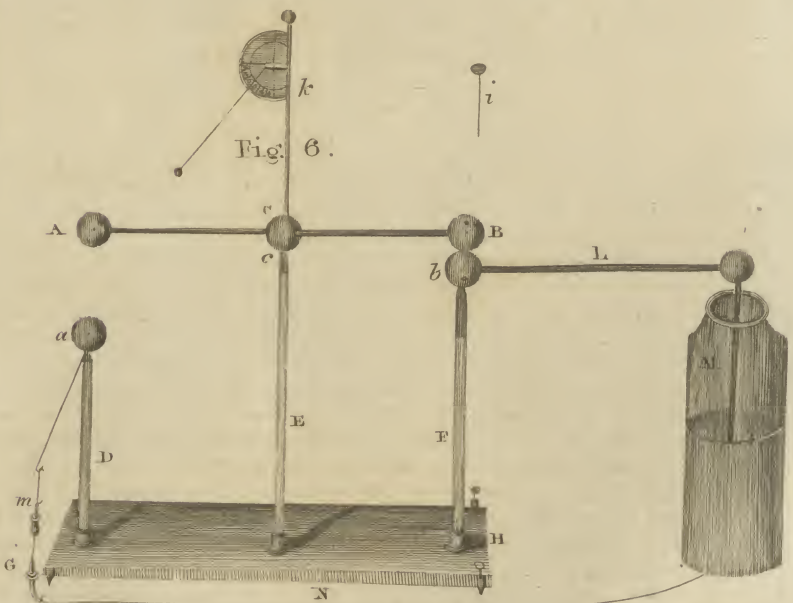
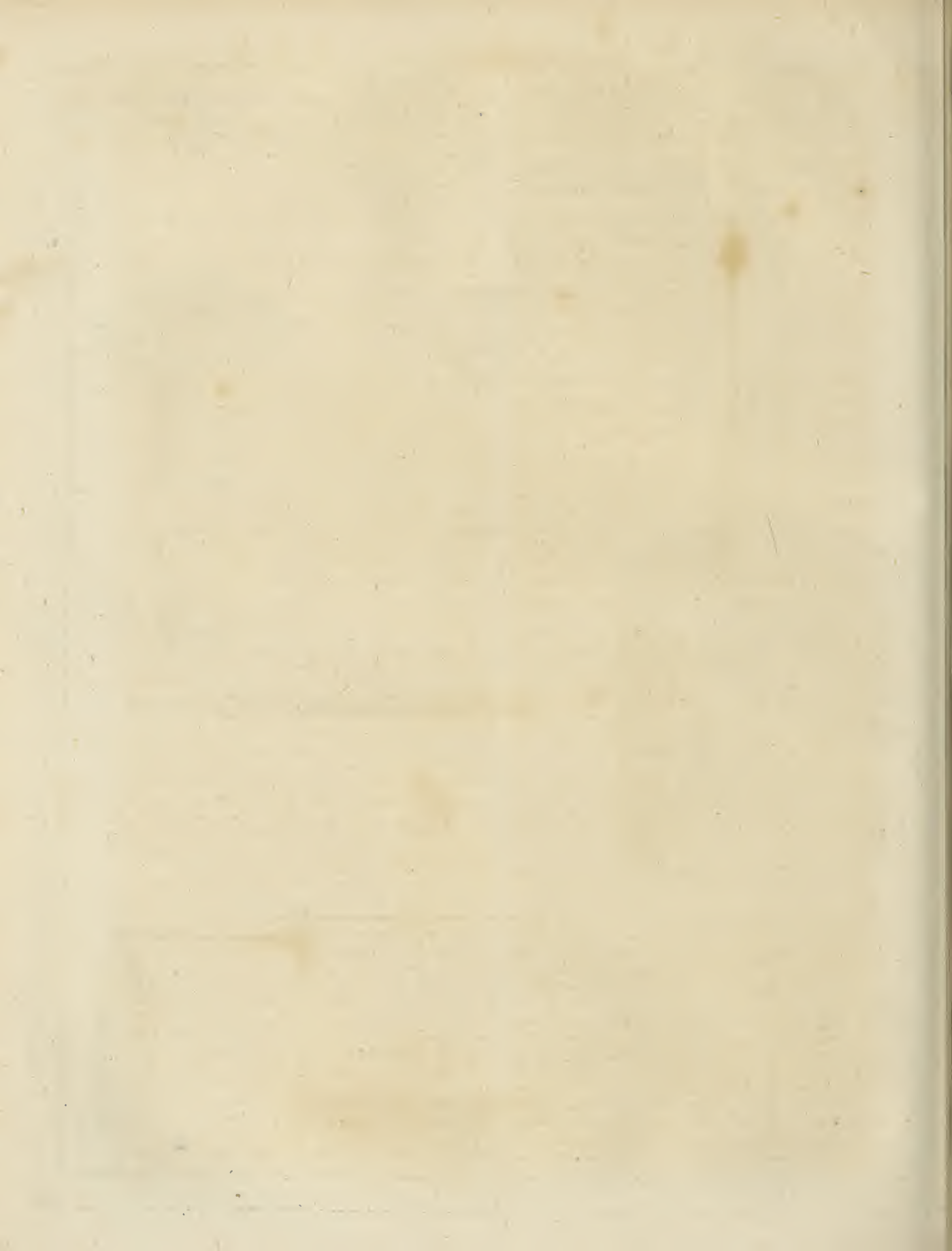


Fig. 6.



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tions, popularly called an *oval*; being called an *ellipse* or *ellipsis* by Apollonius, the first and principal author on the conic sections, because in this figure the squares of the ordinates are *less* than, or *defective* of, the rectangles under the parameters and abscisses. See *CONIC Sections*, *Encycl.*

ELLIPSOID, is an elliptical spheroid, being the solid generated by the revolution of an ellipse about either axis.

ELLIPTOIDE, an infinite or indefinite ellipsis, defined by the indefinite equation $ay^{m+n} = bx^m \cdot a - x^n$ when m or n are greater than 1: for when they are each = 1, it denotes the common ellipse.

There are several kinds or degrees of ellipptoides, denominated from the exponent $m + n$ of the ordinate y . As the cubical ellipptoid, expressed by $ay^3 = bx^2 \cdot a - x^2$; the biquadratic, or surfsolid $ay^4 = bx^2 \cdot a - x^2$; &c.

EMINENTIAL EQUATION, a term used by some algebraists, in the investigation of the areas of curvilinear figures, for a kind of assumed equation that contains another equation eminently, the latter being a particular case of the former.

ENAMELLING OF VESSELS FOR THE KITCHEN. In the year 1779 the Society of Emulation in Paris proposed as a prize question, "To discover a composition fit for making kitchen utensils which should be free from the disadvantages attending copper, lead, tinned vessels, glazed earthen-ware, &c. which should be as strong as possible, less costly than the vessels used at present, and which should be able to bear the highest degree of kitchen fire, and the most sudden changes from heat to cold."

In consequence of this proposal, MR SVEN RINMAN of the Royal Academy of Stockholm, without any intention of being a candidate for the premium offered by the Society of Emulation, instituted a set of experiments on small vessels of copper and hammered iron, with the view of giving to them a coating of what may properly be called *enamel*, which should not have the defects of tinning, and which, when applied to iron, should take from it the inconveniency of rusting, and of blackening many sorts of victuals when they are dressed in it. These experiments he submitted to the academy, of which he was a member; and as we think them important, we shall lay the substance of them before our readers.

The most common, and the cheapest, kind of white enamel that is to be met with in the shops (which is an opaque white glass, composed of powdered quartz, of glass of lead, and of calx of tin), was tried for coating kitchen-utensils; and he found that it was excellent for the purpose, as it produced a coating, which was not only clean and agreeable in its appearance, but possessed likewise all the power of resisting the action of fire and of acids that could be desired. But, as it is very difficult to apply, is very dear for common use, and is besides considered as not being capable of resisting violent blows or falls, he made various experiments with substances of less price; of which the following are certainly worthy of being related.

1. The white semi-transparent fluor spar was reduced into a fine powder, with an equal quantity of unburnt gypsum, and afterwards calcined in a strong fire with a white heat; the whole being, from time to time, care-

fully stirred. The vessel which he intended to coat, having first been wetted by dipping it in water, had as much of the aforesaid powder applied to its inside, by means of a very fine silk sieve, as would adhere to it of itself, or could be made to do so by pressing it with the finger. After this vessel had been dried and gradually heated, it was exposed to a sudden and violent heat, partly in a coal-fire, kept up by a pair of bellows (the vessel being at the same time covered, so that no coals or ashes could fall into it), and partly in an assaying furnace.

In the coal-fire, and with a heat as violent as is commonly used to make copper-folder run, the mixture was melted, in about the space of a minute, into an opaque white enamel, which evenly covered the surface of the copper, and fixed itself pretty firmly to the metal; it also bore hard blows without breaking, and resisted the trials made by boiling things in it, and by applying acids to it. The forementioned mixture was also reduced into a fine powder in a glass mortar, and made into a sort of thin paste with water; it was then applied to the vessel with a small brush, an operation as easy as that of applying any other wet colouring matter. He likewise tried this paste, by covering vessels with it in the same way the potters apply their common glazing for stone-ware. By both the above-mentioned processes he obtained a very smooth coating, particularly by the latter, which is more quickly performed. When the paste is applied, the vessel should be made a little warm, so also should the paste itself.

If the constituent parts of these two substances be considered (that is to say, that gypsum is composed of calcareous earth saturated with vitriolic (sulphuric) acid, and fluor spar of a particular acid united to siliceous earth; also, that the whole, when put into the fire without the addition of any other substance, is, of all earthy or stony mixtures, that which the most easily melts into an opaque white glass, not very brittle), and if, on the other hand, the action of acids be attended to—we shall easily conceive these substances must attach themselves strongly to copper, and that the varnish formed by them cannot afterwards be dissolved or acted upon by acids.

The greatest difficulty attending on this simple mixture is, the strong and sudden heat necessary to apply it with effect, that heat being greater than is commonly to be obtained in an assaying furnace. On that account, M. Rinman endeavoured to render it more fusible by the addition of some other substance.

Of his experiments made with this view, some failed, and others succeeded. We shall record only such as were successful, and at same time attended with such moderate expence as not to preclude them from common use.

2. With the substances employed in his first experiment, which, with the author, we shall henceforth call n^o 1. he mixed an equal quantity of what is called *fusible glass* (*vitrum fusibile*), composed of six parts of lime, four of fluor spar, two of quartz reduced into a fine powder, and one tenth of a part of manganese; the whole having been calcined, and ground with water in the manner colours are ground, he spread it on the vessel with a brush. This mixture ran pretty well upon the copper in the coal fire; it also attached itself very strongly to it, and produced an enamel which was firm and hard, and seemed likely to bear wear; but it was of a dark grey colour, and without any brillian-

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cy. The mixture did not melt more readily in the assaying furnace.

Two parts of n° 1. with one part of the fusible glass, and a quarter of a part of manganese, had nearly the same effect. This last mixture, indeed, was rather more easily melted, but it had a darker colour.

3. Eight parts of n° 1. with one half of a part of borax, one quarter of a part of nitre, and half a part of manganese, were melted, in the space of ten minutes, into a brown liver-coloured glass; which, in the assaying furnace, produced upon the copper vessel a black enamel, which had a dull surface. In other respects it was firm, even, and hard; but it did not sufficiently cover the vessel by a single application, nor was it capable of resisting the action of acids.

4. One part of the brown glass mentioned in the last experiment, with three parts of n° 1. became in the assaying furnace with a red heat, almost as fluid as the last, and held an even and smooth surface; but it was of a dark colour, and had not any brilliancy. It was not sensibly acted upon by vitriolic (sulphuric) acid.

5. Four parts of n° 1. mixed with one half of a part of litharge, were melted in a crucible, with the help of the bellows, in five minutes, so as to become as fluid as water. This mixture, during the fusion, emitted a smell of sulphureous acid, and formed an opaque glass of a straw colour; which, after being ground, as usual, and spread upon a copper vessel, produced an enamel which covered the vessel very evenly, and was without bubbles. It was likewise, perhaps, the hardest of all, but could not be melted in the assaying furnace, requiring a stronger fire kept up by the bellows. It preserved its straw colour, but without any lustre, and resisted the action of acids better than the common glazing of the potters.

6. Mr Rinman mixed together equal quantities of gypsum, fluor spar, and what the potters call *white lead* (A), and which serves for the basis of their glazing. This mixture, after being calcined, melted in five minutes, with the assistance of a pair of bellows, into a very white, hard, and opaque enamel, which was very easily poured out of the crucible. This enamel, treated like the others, ran very freely, equally, and without bubbles, by the heat of the assaying furnace. It was also pretty hard and strong, but without any lustre, and had green and yellow spots, occasioned by the acids of the gypsum and fluor spar, which had acted upon the copper during the fusion of the enamel. It, however, bore melting two or three times, and then appeared of a white colour; it was but very little affected by other acids.

7. Equal parts of fluor spar, of gypsum, of litharge, and of pure flint glass, powdered and mixed together, melted in five minutes, by the help of a pair of bellows, and produced a white and hard glass, very like that of the last experiment, but rather harder. After being applied on the vessel in the usual manner, it formed, with the greatest heat of an assaying furnace, an enamel of a yellowish white colour, firm and hard, but without lustre. In order to avoid the formation of bubbles, care was taken (as ought always to be done

in enamelling) to remove the vessel from the fire as soon as it had acquired a brilliant appearance therein, or as soon as the enamel was completely melted.

8. Twelve parts of glass of lead, or of litharge, with eight parts of flint glass, and two of flowers of zinc, were melted, in the space of seven minutes, into a clear yellow glass, which, when used for enamelling, was disposed to form bubbles; but, by continuing the heat for a longer time, the bubbles were dispersed; and he obtained a pretty good enamel, of a yellow brown colour with a greenish cast, very hard and firm. It resisted the action of the vegetable acids, like the enamels already spoken of, but it was a little attacked by the mineral acids.

9. He powdered and mixed together five parts of flour spar, five parts of gypsum, two parts of minium, one half of a part of borax, two parts of flint glass, one half of a part of calx of tin, and only one twenty-fifth of a part of calx of cobalt. This mixture was melted in a crucible in six minutes, by help of the bellows, and produced an opaque glass of a pearl colour, a little inclining to blue, on account of the calx of cobalt. It was pretty hard, and, after being ground with water in the usual way, it became of a very good consistence, so as to be very fit for spreading over vessels, to which it adhered very strongly. If any bubbles formed on the vessel during its drying, they might be rubbed down with the finger, and the whole surface rendered smooth and even. After being warmed, and gradually heated, it was put into an assaying furnace made very hot with birch charcoal, which had been just kindled under the muffle. After a minute it melted, and began to appear brilliant; so that he found it necessary to take out the vessel very quickly, which was already very evenly coated with a thick, and sufficiently hard, enamel, the surface of which, however, had no brilliancy.

The colour remained always inclining to green, because the copper had been a little attacked by the acids of the gypsum and flour spar during the fusion; but in other respects this enamel was very firm, was very little hurt by slight blows, and bore very well sudden changes of heat and cold. Weak acids had no action upon it; but he had some reason to think that it would, in length of time, have been acted upon, to a certain degree, by vitriolic (sulphuric) acid. Its colour, except the forementioned shade of green, was white, with a dull, and rather changeable surface.

The calx of cobalt which has been just mentioned, and which Mr Rinman made use of merely with the intention of obtaining a fine colour, was prepared by saturating a solution of cobalt in aquafortis (nitric acid) with common salt, and evaporating to dryness; by which means he obtained a fine rose-coloured calx. A very small quantity of this calx, when mixed with any fusible glass, gives it a beautiful blue colour.

Of the various species of enamel, which had been described in the course of these experiments, and which may be all applied, with more or less advantage, to kitchen utensils, the least expensive are n°s 1, 2, and 5; but they are also those which require the greatest heat. On the other hand, n° 9. may be recommended

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(A) This substance is itself a mixture, being composed of four parts of lead and one of tin.

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as the most easy of fusion, and, at the same time, very durable when used for coating vessels in which victuals are to be dressed, which is here the principal object, and is of far greater importance than the brilliant appearance resulting from the enamel generally used by artists, which however may be employed when the saving of expence is not regarded.

The enamels hitherto described are not applicable to vessels made of iron, though they may be employed to cover copper with great advantage. Iron will not indeed bear the common practice of enamellers, namely, to be put into the fire and taken out again several times; for the sparks which fly from iron, when in a hot fire, detach and carry off the enamel from the parts contiguous to those where the sparks are formed. The acids, too, of the gypsum and fluor spar, made use of in the enamels already mentioned, acted upon the iron during the fusion of the enamel, from which resulted bubbles and bare spots, which entirely spoiled the appearance of the work. Our author therefore continued his experiments with a view to discover a proper enamel for vessels made of this metal.

10. He reduced into a very fine powder, and ground together, nine parts of minium (red oxide of lead), six parts of flint glass, two parts of pure potash, two parts of purified nitre, and one part of borax. This mixture was put into a large crucible, which it only half filled; he covered the crucible so that no coals could fall into it, and gradually increased the fire under it. When the effervescence had entirely ceased, he caused the mixture to melt, by using the bellows for four or five minutes; by these means he obtained a clear and compact glass, which he poured out of the crucible upon a piece of marble. Having quenched it in water, and reduced it to a very fine powder in a glass mortar, he ground it with water to the consistence of a very thin paste. He then covered an iron vessel with it on both sides, which, after having dried and heated it by degrees, he put under a muffle well heated in an assaying furnace. The enamel melted very readily in the space of half a minute, and with a very brilliant appearance. He immediately withdrew the vessel, and let it cool: it was found to be entirely coated with a beautiful enamel of a black colour; which colour appeared to be caused by a thin layer of calcined iron, which might be seen through the transparency of the enamel.

A copper vessel having been covered with the same enamel, the fine colour of the copper was visible through the thin coat of glass; and it was as well defended from rust by this coating as it would have been by an enamel of a stronger kind.

11. To hinder the colour of the metal from being seen through the coating, he added to the mixture, used in the preceding experiment, only one hundredth part of the calx of cobalt described in n^o 9. The whole was melted into a beautiful blue glass; it was prepared for enamelling, and applied in the manner before described, upon another iron vessel. The enamel proved to be smooth, thick, and brilliant, like the preceding, but it covered the vessel more perfectly; it was of a fine blue colour, with some black spots in those parts where it had been most thinly applied.

12. The glass of n^o 10. reduced into powder, and ground with potters white lead, of which mention has

already been made, melted with the same facility; it produced a very smooth enamel, of a grey colour, but more firm and hard than the former, and, on account of the addition made to it, of a still less price. By mixing with the same glass a small quantity of crocus martis, he obtained a very fine enamel, of a dark red colour, not to mention other colours in it still more beautiful. The crocus martis he used in this experiment was prepared from a solution of iron in aqua regia (nitro-muriatic acid), which was evaporated to dryness, and the matter thus edulcorated and calcined.

13. In order to render the forementioned enamel more solid, and to give it what is called *body*, he melted together a mixture of twelve parts of flint glass, eighteen parts of minium, four parts of potash, four parts of nitre, two parts of borax, three parts of calx of tin, and one eighth part of calx of cobalt, observing always the usual precautions. He obtained a glass of a light blue colour, which, after having been ground with water, and spread upon small iron basins, or tea cups, produced, by means of a brisk fire in an assaying furnace, an enamel which was smooth and even, and of a pearl colour. The coating was of a proper thickness, to obtain which requires a certain degree of dexterity and practice. He also tried to paint upon this enamel with what is called *mineral purple* (*purpura mineralis*), which he used with a little powdered quartz, nitre, and borax; it produced a very beautiful red colour.

Though this last mentioned composition is more beautiful when applied upon iron, and more even than the preceding, it has the disadvantage, on account of the salts which it contains, of not resisting the action of the stronger vegetable acids, and still less that of the mineral ones. But as a vessel when coated with this enamel bears, without any injury, sudden changes of heat and cold, and also to have any greasy mixtures baked or boiled in it (even those which are of a caustic alkaline nature, or those which contain the usual weak acids which are used in the preparation of our food), it may be applied to vessels of various kinds, among others, to tea cups; particularly as it is neither brittle nor subject to crack, provided it is not exposed to violent blows. It is hardly necessary to say, that this enamel can only be applied upon vessels made of hammered iron, and not upon those of cast iron, these last being always too thick to be heated with sufficient quickness; for the greater is the space of time necessary to make the vessels red hot, the greater is the quantity of scales formed upon them, and, of course, the enamel becomes more injured.

Our author makes some other judicious observations on the enamel for iron, of which he has described the composition, and says, that, independent of its use for coating kitchen utensils, it might be made to serve many other purposes, such as preserving things made of that metal, not only from rust, but also, as he proved by experiment, to a certain degree, from calcination.

ENCAUSTIC PAINTING. See PAINTING in this

Supplement.

ENFIELD (William, L. L. D.), well known in the learned world by several useful and elegant publications, was born at Sudbury, on March 29. O. S. 1741, of parents in a humble walk of life, but of very respectable characters. His amiable disposition and promising talents early recommended him to the Rev.

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Mr Hextall, the dissenting minister of that place, who took great care of his education, and infused into his young mind that taste for elegance in composition which ever afterwards distinguished him.

In his 17th year he was sent to the academy at Daventry, then under the direction of the Rev. Dr Ashworth, where he passed through the usual course of instruction preparatory to the office of the ministry; and with such success did he cultivate the talents of a preacher, and of an amiable man in society, that, on leaving the academy, he was at once chosen, in 1763, minister of the very respectable congregation of Benn's Garden in Liverpool.

In that agreeable town he passed seven of the happiest years of his life, very generally beloved and esteemed. He married, in 1767, the daughter of Mr Holland draper in Liverpool, with whom he passed all the rest of his days in most cordial union. His literary reputation was extended, during his residence in this place, by the publication of two volumes of sermons, which were very well received, and have served to grace many pulpits besides that in which they were originally preached. A collection of hymns and of family prayers, which he also published at Liverpool, did credit to his taste and judgment.

About 1770, he was invited to take a share in the conduct of the academy at Warrington, and also to occupy the place of minister to the dissenting congregation there, both vacant by the death of the Rev. Mr Seddon. His acceptance of this honourable invitation was a source of variety of mixed sensations and events to him, of which anxiety and vexation composed too large a share for his happiness. No assiduity on his part was wanting in the performance of his various duties; but the diseases of the institution were radical and incurable; and perhaps his gentleness of temper was ill adapted to contend with the difficulties, in matter of discipline, which seem entailed on all dissenting academies, and which, in that situation, fell upon him, as the domestic resident, with peculiar weight. He always, however, possessed the respect and affection of the best disposed of the students; and there was no reason to suppose that any other person, in his place, could have prevented that dissolution which the academy underwent in 1783.

During the period of his engagement there, his indefatigable industry was exerted in the composition of a number of works, mostly, indeed, of the class of useful compilations, but containing valuable displays of his powers of thinking and writing. The most considerable was his "Institutes of Natural Philosophy" (quarto, Johnson, 1783); a clear and well-arranged compendium of the leading principles, theoretical and experimental, of the sciences comprised under that head. And it may be mentioned, as an extraordinary proof of his diligence and power of comprehension, that, on a vacancy in the mathematical department of the academy, which the state of the institution rendered it impossible to supply by a new tutor, he prepared himself, at a short warning, to fill it up; and did fill it with credit and utility, though this abstruse branch of science had never before been a particular object of his study. He continued at Warrington two years after the academy had broken up, taking a few private pupils.

In 1785, receiving an invitation from the principal

dissenting congregation at Norwich, he accepted it, and first fixed his residence at Thorpe, a pleasant village near the city, where he pursued his plan of taking a limited number of pupils to board in his house. He afterwards removed to Norwich itself; and, at length, fatigued with the long cares of education, entirely ceased to receive boarders, and only gave private instructions to two or three select pupils a few hours in the morning. This too he at last discontinued, and devoted himself solely to the duties of his congregation, and the retired and independent occupations of literature. Yet, in a private way and small circle, few men had been more successful in education, of which many striking examples might be mentioned, and none more so than the members of his own family. Never, indeed, was a father more deservedly happy in his children; but the eldest, whom he had trained with uncommon care, and who had already, when just of age, advanced in his professional career so far as to be chosen town-clerk of Nottingham, was most unfortunately snatched away by a fever a few years since.

This fatal event produced effects on the doctor's health which alarmed his friends. The symptoms were those of *angina pectoris*, and they continued till the usual serenity of his mind was restored by time and employment. Some of the last years of his life were the most comfortable: employed only in occupations which were agreeable to him, and which left him master of his own time; witnessing the happy settlement of two of his daughters; contracted in his living within the domestic privacy which he loved; and connected with some of the most agreeable literary companions, and with a set of the most cordial and kind-hearted friends that perhaps this island affords, he seemed fully to enjoy life as it flowed, and indulged himself in pleasing prospects for futurity. Alas! an unsuspected and incurable disease was preparing a sad and sudden change: a schirrous contraction of the rectum, the symptoms of which were mistaken by himself for a common laxity of the bowels, brought on a total stoppage, which, after a week's struggle, ended in death. Its gradual approach gave him an opportunity to display all the tenderness, and more than the usual firmness of his nature. He died November 3. 1797, amidst the kind offices of mourning friends, and his last hours were peace!

Besides the literary performances already mentioned, Dr Enfield completed, in 1791, the laborious task of an abridgment of "Brucker's History of Philosophy," which he comprised in two volumes quarto. It may be truly said, that the tenets of philosophy and the lives of its professors were never before displayed in so pleasing a form, and with such clearness and elegance of language. Indeed it was his peculiar excellence to arrange and express other mens ideas to the utmost advantage. Perhaps, at the time of his decease, there was not in England a more perfect master of what is called the middle style in writing, combining the qualities of ease, elegance, perspicuity, and correctness, entirely free from affectation and singularity, and fitted for any subject. If his cast of thought was not original, yet it was free, enlarged, and manly. What he was in the capacity of a teacher of religion, his several congregations will testify with grateful and affectionate remembrance. Few ministers have paid such unremitting attention to the perfection of their pulpit compositions;

Enfield.

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sitions; nor was it only by detached discourses that he inculcated the truths of morality and religion, but by methodical plans of instruction, drawn up with great care and comprehension. The valuable stores of this kind which he left behind him will not be consigned to oblivion; but, it is hoped, will inform and improve numbers to whom the voice of the preacher could never have extended. In delivery, his manner was grave and impressive, depending rather on the weight of just enunciation than on the arts of oratory. Little need be added to this sketch of the moral qualities of the excellent man above commemorated. If moderation, compliancy, and gentleness were ever prevalent in him to a degree of excess, who that knew him will blame an excess which opened his soul to every emotion and office of affection and friendship?

This account of Dr Enfield, which is taken from the *Monthly Magazine*, is acknowledged by its author to be the effusion of friendship; but we believe that the panegyric, though high, is in general just. It is our duty, however, to warn our readers against placing implicit confidence in the Doctor's representation of ancient philosophy; for though we have frequently found him correct, and have therefore quoted him with approbation ourselves, we have likewise found him sometimes mistaking the sense of his authors. In a work like his, mistakes were indeed unavoidable; for when he resolved to compress the substance of Brucker's five volumes within the compass of two, he could not avoid sometimes giving what he thought the *sense* of the ancients, when accuracy required their very words to be given. This we believe to be the source of those errors in his elegant history, which we have heard others unjustly attribute to design; for had it been his *design* to deceive, he would not surely have stored his margin with references to enable every reader to detect the deceit.

ENGINEER, is the appellation of him whose profession it is to contrive or make any kind of useful engine or machine. He is denominated either a civil or military engineer, according as the objects of his profession respect civil or military purposes. See FORTIFICATION, *Encycl.* and MACHINE in this *Supplement*.

ENGONASIS, in astronomy, the same as Hercules, one of the northern constellations.

ENGRAFTING. See GRAFTING, *Encycl.* where it is said that there is little hope of producing mixed fruits by engrafting one tree upon another of the same class. We confess ourselves to be unwilling to relinquish this opinion; but it would be very unfair to withhold from the public any fact which seems to militate against it, and has come to our knowledge. We shall therefore transcribe from the *Philosophical Magazine* the following communication from Dr Thornton, lecturer on medical botany at Guy's Hospital, respecting a supposed *lusus nature*, which he considers as the consequence of engrafting.

In the first volume of the *Philosophical Transactions*, No 29. published November 1667, you have the following communication, intitled,

“Some Hortulan Experiments about the engrafting

of Oranges and Lemons or Citrons, whereby is produced an individual Fruit, half Orange and half Lemon, growing together as one Body upon the same Tree.”

We have here orange trees (saith the intelligence from Florence) that bear a fruit which is citron on one side and orange on the other. They have been brought hither out of other countries, and they are now much propagated by engrafting. This was confirmed to us (saith the editor of the *Transactions of the Royal Society*) by a very ingenious English gentleman, who asserted, that himself not only had seen, but bought of them, anno 1665, in Paris, whither they had been sent by Genoa merchants; and that on some trees he had found an orange on one branch and a lemon on another branch (which is not so remarkable as what follows); as also, one of the same fruit, half orange and half lemon; and sometimes three quarters of one and a quarter of the other.

In the third part of the Reports of the Board of Agriculture, among the foreign communications, we see, with equal pleasure and astonishment, an account of the American apple, which, by a peculiar mode of budding (A), is half sweet and half sour, half white and half red, without the least confusion of the respective halves.

At Mr Mason's, florist, Fleet-street, opposite the Bolt and Tun, there is a production now, September 1798, to be seen half peach and half nectarine. It has all the softness and yellow down of the peach, and the sleek red smoothness of the nectarine; supposed to be a *lusus nature*, but probably is rather the sportings of art than of nature, and which perhaps will be the cause why we shall in future see many other such vegetable wonders, which, as we see, were known to our ancestors.

ENNEADECATERIS, in chronology, a cycle or period of 19 solar years, being the same as the golden number and lunar cycle, or cycle of the moon.

ENSETE. See MUSA, *Encycl.*

EOLIPILE. See ÆOLIPILE, *Encycl.*

EPAULE, or ESPAULE, in fortification, the shoulder of the bastion, or the angle made by the face and flank, otherwise called the angle of the epaule.

EPISCOPACY, the government of the church by diocesan bishops. See *Encycl.*

SCOTCH EPISCOPALIANS, are a society of Christians, certainly as respectable, if not so numerous, as any other in the kingdom which dissents from the worship and discipline of the established church. For many years, however, the public worship of that society was proscribed by the legislature; and there is reason to suspect that its real principles are not yet universally understood. If this be so, it surely becomes the editors of a work in which some account is given of almost every denomination of Christians down to the novel sect which styles its members BEREANS, to do justice to the venerable remains of what was once the established church of their native country.

That the reformation from popery was, in Scotland, tumultuous and irregular, is known to all Europe; and very few of our readers can be ignorant that there was
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neither

(A) the manner in which the extraordinary nectarine-peach first produced in this country was effected, was by inserting the bud of one fruit upon the stock bearing a different sort.

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neither order in the reformed church, nor decency in her worship, till James VI. with much address, accomplished the establishment of a very moderate episcopacy. To this form of church-government the better part of the nation was sufficiently attached; and it continued to be the ecclesiastical polity, supported by the state, till the grand rebellion, when it was overthrown by the partizans of the *national covenant*. It was restored, however, in 1662; and again abolished in 1689 by that convention which placed the Prince and Princess of Orange on the ancient throne of the Scottish monarchs.

2
No liturgy
used in the
Scotch
church,

These events are so universally known, that it is sufficient in this place barely to mention them; but there are probably many of our readers who do not know that, during the whole period of her legal establishment, the Scotch episcopal church had no public liturgy. It appears indeed, that the first reformers made use of the English book of common prayer; and there is on record sufficient evidence that John Knox himself, though he disapproved of some things in that book, had no objection either to stated forms of prayer in general, or to a subordination among the ministers of the gospel; but his successor Andrew Melvil, who possessed neither his learning nor his worth, had influence enough to introduce into the church a perfect parity of ministers, and to excite among the people a very general abhorrence of liturgical worship. So rooted indeed was that abhorrence, that, as every one knows, an attempt to introduce into the church of Scotland a book of common prayer, copied with some alterations from that of England, produced the *solemn league and covenant*, which involved in one common ruin the unfortunate Charles and his darling Episcopacy. At the restoration of the monarchy, the Episcopal constitution of the church was restored, but no new attempt was made to establish the use of a public liturgy; and except at the ordinations of the clergy, when the English forms were used, no service book was seen in a Scottish church.

3
Except at
ordinations.

For some years after Episcopacy had ceased to be the religion of the state, the deprived clergy made no alteration in their modes of social worship. Having refused to transfer to King William that allegiance which they had sworn to King James, they were treated, during his reign, with such severity, that on the Lord's day they durst not venture further than to officiate "in their own hired houses, where they received such friends as chose to come in unto them;" and in those small congregations, if congregations they may be called, they continued to pray, if not extempore, at least without book, till the accession of Anne to the throne of her ancestors. The attachment of that Princess, not only to the constitution, but also to the worship of the church of England, was well known to them; and they very reasonably thought, that they could not more effectually recommend themselves to her protection than by adopting the use of the English liturgy, which the most enlightened among them had long professed to admire. It was accordingly introduced by degrees into Scotland; and an act of parliament being passed on the 3d of March 1712, "to prevent the disturbing of those of the Episcopal communion in that part of Great Britain called Scotland, in the exercise of their religious worship, and in the use of the liturgy of the church of England," that liturgy was universally adopted by the Scotch Episcopals; and public chapels, which had

4
Introduc-
tion of the
English li-
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hitherto been prohibited, were everywhere built, and well frequented.

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That those who had refused allegiance to King William and Queen Anne should scruple to pay it to a new family, clogged as it was by so many oaths, can excite no wonder; nor is it at all wonderful that, for their attachment to the abdicated family, the public worship of the Scotch Episcopals was, after the insurrection of 1715 and 1716, laid under some restraints. These, however, were neither rigorously severe, nor of long duration; and by the year 1720, their congregations were as numerous as formerly, consisting, especially in the northern counties, of men of all ranks, even such as held offices of trust under the established government, who frequented the Episcopal chapels in preference to the parish churches.

Hitherto the Episcopals had been safely conducted through all dangers and difficulties by the prudence of Dr Rose, the deprived bishop of Edinburgh; but soon after his death, which happened on the 20th of March 1720, divisions broke out among them, which threatened to prove more fatal to their church than any persecution to which they had yet been subjected. For reasons which will be seen afterwards, it is proper to trace those divisions from their source.

No native of Britain, who knows any thing of the history of his country, can be ignorant that Dr Sancroft, the archbishop of Canterbury, and five other bishops, were at the Revolution deprived of their sees by an act of parliament; because, like the Scotch bishops, they could not bring themselves to transfer to King William and Queen Mary that allegiance which they had so lately sworn to King James. As those prelates were extremely popular for the vigorous opposition which they had given to some of the Popish projects of the late king, and as a number of inferior clergymen, of great eminence for piety and learning, were involved in the same fate with them—it need not excite great surprize, that a sweeping deprivation, which, in all its circumstances, was perhaps without a precedent in ecclesiastical history, produced a schism in the church of England. The deprived clergy, considering the bishops who were placed in the sees thus vacated as intruders, and all who adhered to them as schismatics, opened separate chapels under the authority of the primate and his nonjuring suffragans; and contended, that they and their adherents constituted the only orthodox and catholic branch of the church in England.

Both churches, however, made use of the same liturgy; and during the lives of the deprived prelates, there was no other apparent difference in their worship than what necessarily resulted from their paying allegiance to different sovereigns. But this uniformity was not of long duration. The bishops, who had been possessed of sees before the Revolution, were scarcely dead, when their successors, being under no civil restraint, found, in the principles which they had brought with them from the establishment, the means, not only of dividing their own little church, but likewise of sowing the seeds of dissension among their brethren in Scotland.

It has been observed elsewhere*, that in the church of England there are three opinions respecting the nature and end of the Lord's Supper, which, in opposition to each other, have been all patronised by men of great eminence for theological learning. It appears, indeed,

5
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lians.

indeed, from the first liturgy set forth by authority in the reign of King Edward VI. that the reformers of that church from the errors of popery unanimously held the Lord's Supper to be a eucharistical sacrifice; and this opinion, which has been adopted by great numbers in every age since, seems to have been the most prevalent of the three among those clergy who were deprived of their livings at the Revolution. It is indeed countenanced by several passages in the present order for the administration of the Lord's Supper; and therefore, though there are other things in that order which cannot be easily reconciled to it, archbishop Sancroft and his suffragans, whatever their own opinions might be, chose not to widen the breach between themselves and the establishment, by deviating in the smallest degree from the form in which they had been accustomed to celebrate that sacrament. Their successors, however, in office, were men of different dispositions. Considering themselves as totally unconnected with the state, and no longer bound by the act of uniformity, one party, at the head of which was bishop Collier, the celebrated ecclesiastical historian (A), judged it proper to make such alterations in the communion office as might render it more suitable to their own notions of the Lord's Supper, and bring it nearer, both in matter and form, to the most ancient liturgies of the Christian church.

Of the proposed alterations, some were perhaps proper in their circumstances; whilst others, to say the best of them, were certainly needless, if not inexpedient. They were accordingly *all* opposed by another powerful party of nonjurors; and the questions in dispute were referred, first to Dr Rose, the deprived bishop of Edinburgh, and afterwards to Dr Atterbury and Dr Potter, the bishops of Rochester and Oxford. What judgment the two English prelates gave in this controversy we know not; but that of bishop Rose did him much honour. Declining the office of umpire between the parties, he recommended mutual forbearance and occasional communion with each other, according to either form; and employed a gentleman, well versed in ecclesiastical literature, to prove that such a compliance of bishop's with each others innocent prejudices was not uncommon in the purest times.

These disputes among the English nonjurors, and the appeal which was made to Dr Rose, drew, more closely than hitherto it had been drawn, the attention of the Scotch Episcopal clergy, not only to their own liturgy, which had been authorized by King Charles I. but like-

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lians.

wise to the most ancient liturgies extant, as well as to what the fathers of the first three centuries have taught concerning the nature of the Lord's Supper. The consequence was, that such of them as were scholars soon discovered, that the Scotch communion office approached much nearer to the most ancient offices than the English; and a powerful party was formed for reviving the use of it in Scotland.

Had those men aimed at nothing farther, it is probable they would have met with very little opposition. Their opponents, who, in general, were less learned than they, were so strongly attached to the house of Stuart, that they would have adopted almost any thing sanctioned by the royal martyr's authority; but the advocates for the Scotch office knew not where to stop. They wished to introduce some other usages of the primitive church; such as the commemoration of the faithful departed, and the mixture of the eucharistic cup (See *SUPPER of the Lord*, n^o 2. and 3. *Encycl.*); and their brethren, perceiving no authority from Charles I. for these things, and being accustomed to consider them as Popish practices, a violent controversy was ready to burst forth about what every enlightened mind must consider as matters of very little importance.

That the eucharistic cup was in the primitive church mixed with a little water, is a fact incontrovertible; that the practice was harmless and decent, it is wonderful that any man should deny: but that such a mixture is *essential* to the sacrament, we cannot believe, for the reasons assigned in the article referred to; and therefore it ought surely to have been no object of contention.

That the faithful departed were commemorated in the primitive church long before the invention of purgatory, is known to every scholar; that in those days such a commemoration tended to invigorate the faith and the charity of Christians, it would, in our opinion, be very easy to prove; and that at present every Christian prays in private for his deceased friends, we have proved elsewhere by arguments, of the confutation of which we are under no apprehension (See *GREEK church* in this *Supplement*): but we see not the *necessity* of introducing such prayers into public worship at any period; and we perceive impropriety in doing it at a period when, from various circumstances, they may cause weak brethren to err. But those who pleaded for the revival of this practice in the beginning of the current century, were blinded by their very erudition (B); and those who opposed it seem not to have been acquainted with

6
Revival of
ancient usages.

(A) This very learned, though violent man, of whom the reader will find some account in the *Encyclopaedia*, was, with Dr Hicke and others, consecrated by the deprived prelates, for the purpose of preserving the Episcopal succession in what they considered as the true church of England.

(B) Paradoxical as this assertion may at first sight appear, nothing is more certain than that erudition, and even science, if *partially* cultivated, is as likely to blind as to enlighten the understanding. When a man devotes all his time, and all his attention, to *one* pursuit, he contracts such a fondness for it, as gradually to consider it as the *only* valuable pursuit, which will infallibly lead to truth, and to nothing but truth; and in this disposition of mind, he is ready to embrace the most extravagant absurdity to which it may conduct him. Of this the reader will find one very striking instance in page 547 of this volume, where the celebrated Euler appears so devoted to his darling analysis, as to place implicit confidence in it, even when he himself seems sensible that it had led him to a conclusion contrary to common sense, and the nature of things. That Dr Bentley was a very eminent philologist, is universally known; that his emendatory criticisms on the Classics are often happy, no man will deny; and yet, misled by his favourite pursuits, he never pronounces more dogmatically than when the dogma which he utters is untenable. We appeal to his criticisms on Milton. Perhaps there is not a man alive

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with the workings of a benevolent and devout mind, or indeed to have known in what the essence of a prayer consists.

The ancient usages, however, were not the only subjects which, on the death of bishop Rose, furnished matter for controversy among the Scotch Episcopalians. That excellent prelate, together with the deprived archbishop of Glasgow, and the deprived bishop of Dunblain, had, from time to time, as they saw occasion, raised to the Episcopal dignity some of the most deserving Presbyters of the church; but it was resolved, for what reason we do not very well know, that none of the new bishops should be appointed to vacant dioceses during the life of any one prelate who had possessed a legal establishment; so that bishop Rose, who survived all his brethren, was for several years the ecclesiastical governor of the whole Episcopal church in Scotland. On his death, therefore, though there were four bishops in Scotland, and two Scotch bishops residing in London, there was not one of those prelates who could claim to himself the authority of a diocesan over any portion of the Catholic church. This they at first unanimously acknowledged; and one of them, in the name of himself and his brethren, recommended to the clergy of the diocese of Edinburgh to elect, after the primitive plan, a successor to their late venerable diocesan. The advice was followed; the election was made, and approved by the bishops: and Dr Fullarton, the bishop chosen, became bishop of Edinburgh, by the same means and the same authority as, in the primitive church, St Cyprian became bishop of Carthage, or Cornelius bishop of Rome.

The clergy in other districts, following the example of those in Edinburgh, diocesan Episcopacy was about to be revived throughout all Scotland upon principles purely ecclesiastical, when some of the bishops, whom Dr Rose had left behind him merely for preserving the Episcopal succession, conceived a new and very extraordinary constitution for the Scotch Episcopal church. Whether they were envious of their colleagues, and offended that none of the elections had fallen upon them; whether they were so ignorant as not to know that diocesan Episcopacy had subsisted long before the conversion of the Roman empire, in absolute independence on the state; or that they were actuated, as there is reason to suspect, by some political principle which they could not with safety avow;—so it was, that they opposed diocesan Episcopacy of every kind, and proposed to govern the whole Scotch church by a college

7
College of
bishops.

of bishops. Against this unprecedented scheme the more learned bishops opposed all their influence; and being exceedingly disagreeable to the inferior clergy, it was very soon abandoned by its authors themselves, who, after some acrimonious controversy, were glad to come to an agreement with their diocesan brethren.

Of this agreement, or *concordate* as it was called, the following were the principal articles: 1. "That the Scotch or English liturgy, and no other, might be indifferently used in the public service; and that the peace of the church should not be disturbed by the introduction of any of the ancient usages which had lately excited such dissensions. 2. That no man should thenceforward be consecrated a bishop of the Scotch church without the consent and approbation of the majority of the bishops. 3. That the bishops, by a majority of voices, should choose one of their number to preside in the meetings of his brethren, and to convocate such meetings when he judged them necessary: that this president should be stiled *Primus Episcopus*, or more shortly *Primus*; but that he should not possess metropolitanical power, or claim any kind of jurisdiction without the bounds of his own diocese or district. 4. That upon the vacancy of any diocese or district, the presbyters should neither elect, nor submit to, another bishop, without receiving a mandate by the *Primus*, issued with the consent of the majority of his colleagues."

This concordate was in 1731-2 subscribed by all the bishops then in Scotland, who immediately became diocesans, and thought no more of the college system. It was afterwards, with a few additions, for ascertaining more precisely the prerogatives of the *Primus*; for regulating the conduct of synods; for exempting bishops from the jurisdiction of other bishops, in whose districts they might chance to reside; and for preventing inferior clergymen from deserting their congregations, or removing from one district to another, without the consent of the bishops of both—thrown into the form of canons; and these canons have continued to be the code of the Scotch Episcopal church down to the present day.

The members, and more especially the clergymen of this church, had always been considered as unduly attached to the family of Stuart; and though there was undoubtedly at first some ground for that suspicion, the writer of this article knows, from the most incontrovertible evidence, that it was continued too long, and carried by much too far. Jacobitism was imputed

alive who will refuse to Dr Warburton the praise of learning and ingenuity. The address with which he detects the double doctrines of the ancient philosophers, is sometimes almost astonishing; yet, misled by his own ardour in this pursuit, he discovers hidden meanings everywhere, and has found a rational system of religion in some of the ancient mysteries, where there is every reason to believe that nothing in reality was to be found but atheism and vice. Just so it is with the ardent reader of the Christian fathers. If he devote all his time to the study of their writings, he not only becomes enamoured of his employment, but acquires gradually such a veneration for the character of his masters (and venerable they undoubtedly are) as renders him afraid to question any thing which they advance, and unable to distinguish between their testimony, which is deserving of all credit, and their reasonings, which are often inconclusive. We trust it is needless to disclaim any wish to discourage, by this note, the study either of the Christian fathers, the Greek philosophers, philological criticism, or the modern analysis; we only wish to dissuade men of letters from devoting their whole time to any one pursuit whatever; for they may depend upon it, that such *partial* studies contract the mind. One of the most eminent mathematicians at present in England is reported to have declared his contempt of the *Paradise Lost*, because he found in it nothing *demonstrated!*

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ted to the society as its distinguishing tenet; but the members of that society have at all times contended, that their distinguishing tenets were the apostolical institution of Episcopacy, and in the exercise of those powers which are purely spiritual, the independency of the church upon the state. In politics, indeed, they have unanimously maintained, that the only ruler of princes or legislatures is God, and not the people. They are, of course, no friends to the fashionable doctrine of resistance, which they believe to be not only condemned in express terms by Christ and two of his apostles, but to be also the source of that anarchical tyranny which lately deluged Europe with blood. They consider a limited monarchy, like that of Britain, as the most perfect form of civil government which the world has ever seen; and hereditary monarchy is infinitely preferable to one that is elective: and with respect to the title of the monarch, when they take a retrospective view of the origin of all civil governments, they cannot but look upon a permanent and unquestioned establishment as an indication of the plan and determination of Providence furnishing the best right to a crown which any modern sovereign can claim.

10
Persecution

Surely these are harmless opinions; and yet the worship of those who held them was, in 1746 and 1748, laid under such restraints as were calculated to produce disaffection where it did not previously exist. Two laws were then enacted against the Scotch Episcopalians; which, under the pretence of eradicating their attachment to the house of Stuart, were so contrived as to preclude such of their clergy as were willing to pay allegiance to the reigning sovereign, and to pray for the royal family by name, from reaping the smallest benefit from their loyalty. The experiment was tried by some of them; of whom one venerable person, who was never suspected of undue attachment to the house of Stuart, is still alive; but he, and his complying brethren, had their chapels burnt, and were themselves imprisoned, as if they had been the most incorrigible Jacobites. This was a kind of persecution which, since the Reformation, has had no precedent in the annals of Britain. A priest of the church of Rome, by renouncing the errors of Popery, has at all times been qualified to hold a living in England; a dissenting minister, of whatever denomination, might at any time be admitted into orders, and rise to the highest dignities of the English church;—but while the laws of 1746 and 1748 remained in force, there was nothing in the power of a Scotch Episcopal clergyman to do from which he could reap the smallest benefit. By taking the oaths to government, he was not qualified to hold a living in England, or even to enjoy a toleration in Scotland; and his clerical character being acknowledged by the English Bishops, he could not by those prelates be canonically reordained.

11
Toleration.

Upon the clergy, however, those laws of uncommon rigour were not long rigorously executed. After a few years, the burning of chapels, and the imprisoning of ministers, were occurrences far from frequent; but the laws to which we allude affected likewise the political privileges of such laymen as frequented the Episcopal chapels: and in that part of their operation, those laws were never relaxed till 1792, when they were wholly repealed, and the Episcopalians in Scotland tolerated like other well affected dissenters from the national establishment.

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12
Faith of
the Scotch
Episcopal
church.

While Episcopacy was the established form of church government in Scotland, the clergy of that church subscribed a confession of faith summed up in twenty five articles; which the reader will find in the history attributed to John Knox. It is sufficient to observe in this place, that in essentials it differs little from the articles of most other reformed churches; and in every thing which does not immediately relate to *papistry*, it is moderate and unexceptionable; perhaps more so than the present confession of either of the British churches. During the period which intervened between the Revolution and the year 1792, no subscription was indeed required from Scotch Episcopalians to any summary of Christian doctrine; but at their ordinations, those clergy solemnly professed their belief of all the canonical books of the Old and New Testaments; declared their persuasion that those books contain sufficiently all doctrines necessary to salvation, through faith in Jesus Christ; and were obliged to read daily in their chapels the English book of Common Prayer, which contains the Apostles, Nicene, and Athanasian creeds. But now those clergymen are enjoined by act of parliament to subscribe the 39 articles of the church of England; so that the principles of their faith are well known. No doubt there are differences of opinion among them about the sense of some of those articles; and it is well known that there are similar differences among the English clergy themselves: but there is every reason to believe, that the faith of the Scotch Episcopalians has, in every important point, been at all times orthodox.

We are aware, that they have been represented as unfriendly to the English service; but such a representation appears to be either a wilful falsehood, or the offspring of ignorance. The only reformed liturgy that ever had the sanction of a civil establishment in Scotland, is *the Book of Common Prayer, and Administration of the Sacraments, and other parts of Divine Service* authorized by King Charles I. In that book, the order of administration of the Lord's Supper differs in some particulars from the English order, and is unquestionably better adapted to the opinions of those who consider that holy ordinance either as an eucharistical sacrifice, or as a feast upon a sacrifice. In the one or other of these lights, the Lord's Supper is viewed by a great majority of the Scotch Episcopalians; and of course the Scotch communion office is used in a great majority of their chapels: but it is not used in them all. Their bishops, who, when in England, communicate with the established church, leave the inferior clergy at liberty to use either the English or the Scotch form, as is most agreeable to themselves and to the people among whom they minister; and to silence the clamour of symbolizing with the church of Rome, which was some years ago either ignorantly or maliciously raised against them, they altered the arrangement of the Scotch prayer of consecration, so as not only to bring it nearer to the most primitive forms, but also to make it absolutely inconsistent with the real presence, as taught either by the church of Rome or by the Lutheran churches. On this subject, see *Greek Church*, n^o 17. in this *Supplement*.

13
Their wor-
ship.

Thus have we given a short view of the distinguish-
ing principles of what must surely be considered as a very respectable society of Christians, and the only re-
formed.

14
English
clergymen.

in Scotland.

Equant
||
Erkoom.

formed *Episcopal* society in that part of Great Britain called Scotland. There are, indeed, chapels in Scotland distinct from the church of which we have been treating, where the English liturgy is read by clergymen who have received Episcopal ordination either in England or in Ireland; but those chapels being all independent of each other, and under the inspection of no bishop, the persons who frequent them seem to be rather Congregationalists than Episcopalians, and certainly do not constitute what can, with any propriety, be called an *Episcopal church*.

EQUANT, in astronomy, a fanciful circle, introduced into science to remove some of the defects of the Ptolemaic system of the universe. In this artificial system of epicycles and eccentric circles, the idea of circular and equable motion was by no means abandoned; but while each of the heavenly bodies revolved in its own orb, the centre of that orb was supposed to be carried at the same time round the circumference of another circle. The more obvious inequalities were thus explained with a geometrical precision. With all its nice combination, however, of circles, the system was soon found to have defects; to remove which, the fine contrivance of the equant was introduced. Though the angular motion of a planet viewed from the earth was confessed to be unequal, a point could be conceived from which it would be seen to move with perfect uniformity. That point was made the centre of the equant, and lay at the same distance from the centre of the eccentricity on the one side, as the earth was removed on the other. "Nothing (says Dr Smith, from whom this account of the equant is taken) can more evidently shew how much the repose and tranquillity of the imagination is the ultimate end of philosophy, than the invention of this equalizing circle."

EQUATION OF A CURVE. See **ALGEBRA** (*Encycl.*) Part III. chap. ii.

Secular EQUATION, in astronomy. See **ASTRONOMY** in this Supplement, n^o 25—38.

EQUICURVE CIRCLE, the same with **CIRCLE of Curvature**, which see in this Supplement.

ERGETT EL KRANE } Two Abyssinian shrubs of
ERGETT Y'DIMMO } the genus MIMOSA, which
see *Encycl.*

ERKOOM, an Abyssinian bird, part of a large tribe, "in which (says Mr Bruce) the greatest variety lies in his beak and horn. The horn he wears sometimes upon the beak and sometimes upon the forehead above the root of the beak." This bird is by naturalists called the *Indian crow or raven*; and our author, though he seems to think this classification improper, admits that he has one characteristic of the raven; he walks, and does not hop or jump in the manner that many others of that kind do; but then he at times runs with very great velocity, and, in running, very much resembles the turkey or bustard when his head is turned from you.

The colour of the eye of this bird is of a dark brown, or rather reddish, cast, but darker still as it approaches the pupil; he has very large eyelashes, both upper and lower, but especially his upper. From the point of the beak to the extremity of the tail is three feet ten inches; the breadth, from one point of the wing to the other extended, is six feet, and the length twenty-two inches; the length of the neck ten inches, and its

thickness three inches and a half; the length of the beak, measuring the opening near the head straight to the point, ten inches; and from the point of the beak to the root of the horn, seven inches and three eighths. The whole length of the horn is three inches and a half. The length of the horn, from the foot to the extremity where it joins the beak, is four inches. The thickness of the beak in front of the opening is one inch and seven eighths. The thickness of the horn in front is one inch and five eighths. The horn in height, taken from the upper part of the point to the beak, two inches. The length of the thighs seven inches, and that of the legs six inches and five eighths. The thickness in profile seven lines, and in front four lines and a half. It has three toes before and one behind, but they are not very strong, nor seemingly made to tear up carcases. The length of the foot to the hinder toe is one inch six lines, the innermost is one inch seven lines, the middle two inches two lines, and the last outer one two inches one line. This bird is all of a black, or rather black mixed with foot-colour; the large feathers of the wing are ten in number, milk-white both without and within. The tip of his wings reaches very nearly to his tail; his beak and head measured together are eleven inches and a half, and his head three inches and a quarter. At his neck he has those protuberances like the Turkey-cock, which are light blue, but turn red upon his being chafed, or in the time the hen is laying.

The erkoom, though not easily raised, flies (says our author) both strong and far. It has a rank smell, and is said in Abyssinia to feed upon dead carcases. This, however, he thinks a mistake, as he never saw it following the army, nor approaching a dead carcase; and as often as he had occasion to open this bird, he found in its stomach nothing but the green scarabeus or beetle. It builds in large thick trees, always, if it can, near churches; has a covered nest like that of a magpie, but four times as large as the eagle's. It places its nest firm upon the trunk, without endeavouring to make it high from the ground: the entry is always on the east side.

ETON is a place which, on account of its college, should not be omitted in a repository of arts, sciences, and literature; and as no notice is taken of it in the *Encyclopædia*, we shall deviate for once from the plan which we had laid down for this Supplement, and which is, not to admit into it descriptions of places in our own island that may be visited by the greater part of our readers with little trouble.

Though in a different county, namely, Buckinghamshire, Eton may be said to be one and the same town with Windsor, for which see *Encycl.* It is pleasantly situated on the banks of the Thames, in a delightful valley, which is of a remarkably healthy soil. Its college was founded by Henry VI. for the support of a provost and seven fellows, one of whom is vice-provost, and for the education of seventy King's scholars, as these are called who are on the foundation. These, when properly qualified, are elected, on the first Tuesday in August, to king's college Cambridge, but they are not removed till there are vacancies in the college, and then they are called according to seniority; and after they have been three years at Cambridge, they claim a fellowship. Besides those on the foundation

Eton.

there

Eton.

there are seldom less than three hundred scholars, and often many more, who board at the masters houses, or within the bounds of the college. The school is divided into upper and lower, and each of these into three classes. To each school there is a master and four assistants or ushers. The revenue of the college is about L. 5000 a-year. Here is a noble library, and in the great court is a fine statue of the founder, erected at the expence of a late provost Dr Godolphin dean of St Paul's. The chapel is in a good style of Gothic architecture. The schools and other parts, which are in the other style of building, are equally well, and seem like the design of Inigo Jones.

At Eton there is a singular, and we think a laudable, festival called the *Montem*, celebrated triennially (formerly duennially) by the scholars of the school upon Whit-Tuesday. The following account of this festival, taken from the Monthly Magazine, will probably be acceptable to many of our readers.

It commences by a number of the senior boys taking post upon the bridges or other leading places of all the avenues around Windsor and Eton soon after the dawn of day. These youths so posted are chiefly the best figures, and the most active of the students; they are all attired in fancy dresses of silks, satins, &c. and some richly embroidered, principally in the habits or fashion of running footmen, with poles in their hands; they are called *salt-bearers*, and demand salt, i. e. a contribution from every passenger, and will take no denial.

When the contribution is given, which is *ad libitum*, a printed paper is delivered with their motto and the date of the year, which passes the bearer free through all other salt-bearers for that day, and is as follows, viz.

“ Pro more et monte,
1799, (A)
Vivant Rex et Regina.”

These youths continue thus collecting their salt at all the entrances for near seven miles round Windsor and Eton, from the dawn of day until about the close of the procession, which is generally three o'clock in the afternoon.

The procession commences about twelve o'clock at noon, and consists of the Queen's and other bands of music; several standards borne by different students; all the Etonian boys, two and two, dressed in officers uniforms; those of the king's foundation wearing blue, the others scarlet uniforms, swords, &c.

The Grand Standard-bearer.

The Captain, or Head Boy of Eton School.

The Lieutenant, or Second Boy.

His Majesty, attended by the Prince of Wales, and other male branches of the royal family on horseback, with their suite.

The Queen and Princesses in coaches, attended by their suite.

Band of music, followed by a great concourse of the Nobility and Gentry in their carriages and on horseback.

The procession commences in the great square at Eton, and proceeds through Eton to Slough, and round to Salt Hill, where the boys all pass the king and queen in review, and ascend the Montem: here an ora-

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tion is delivered, and the grand standard is displayed with much grace and activity by the standard bearer, who is generally selected from among the senior boys.

There are two extraordinary salt-bearers appointed to attend the king and queen, who are always attired in fanciful habits, in manner of the other salt-bearers already described, but superbly embroidered. These salt-bearers carry each an embroidered bag, which not only receives the royal salt, but also whatever is collected by the out-stationed salt-bearers. The donation of the king and queen, or, as it is called upon this occasion, the *royal salt*, is always fifty guineas each; the Prince of Wales thirty guineas; all the other princes and princesses twenty guineas each. As soon as this ceremony is performed, the royal family return to Windsor. The boys are all sumptuously entertained at the tavern at Salt Hill; and the beautiful gardens at that place are laid out for such ladies and gentlemen as choose to take any refreshments, the different bands of music performing all the time in the gardens.

About six o'clock in the evening all the boys return in the same order of procession as in the morning (with the exception only of the royal family), and, marching round the great square in Eton school, are dismissed. The captain then pays his respects to the royal family at the queen's lodge, Windsor, previous to his departure for King's College, Cambridge; to defray which expence, the produce of the montem is presented to him; and upon Whit-Tuesday, in the year 1796, it amounted to more than 1000 guineas. The day concludes by a brilliant display of beauty, rank, and fashion, a promenade on Windsor Terrace, bands of music performing, &c. and the scene highly enlivened and enriched by the affable condescension of the royal family, who indiscriminately mix with the company, and parade the Terrace till nearly dark.

SPONTANEOUS EVAPORATION. See WEATHER, no 17, &c. *Encycl.*

EUDIOMETER, an instrument for ascertaining the purity of the atmospherical air. Many have been the contrivances of chemists for this purpose (see EUDIOMETER, *Encycl.*); but perhaps the best eudiometer is that of *Morveau* (or *Guyton*, as he now chooses to call himself), of which mention has been made in CHEMISTRY, n^o 420. in this Supplement. The following short description will make the nature and use of this instrument plain to every reader.

AB. (Plate XXVIII.) represents a small glass retort with a long neck; its whole capacity being from seven to nine solid inches. It must be chosen of such a curvature that, when the neck is set upright, the bulb may form at its lower part a cavity to retain the matters introduced. The extremity of the neck of this retort is ground with emery to enter the glass tube CD, which is open at both ends, and about 12 or 15 inches in length. The retort then closes the tube in the manner of a ground stopper, and intercepts all external communication. A cylindrical glass vessel F is provided, of the form of a common jar, in which the glass tube CD may be entirely plunged beneath the level of the water. Lastly, the sulphuret of potash is prepared and broken into pieces sufficiently small to be introduced

4 L

into

Eton,
Eudiometer.

Eudiometer,
Eudoxus.

into the retort. These are to be inclosed, dry and even hot, in a bottle for use. These constitute the whole apparatus and preparation of materials.

When it is required to examine an aeriform fluid, by separating its oxygen, two or three pieces of the sulphuret, of the size of a pea, are put into the retort. It is then filled with water, taking care to incline it so that all the air may pass out from the bulb. The orifice of the retort is then to be closed, and inverted into the pneumatic tube, in order that the gas proposed for examination may be transferred into it in the usual manner. By an easy manœuvre of alternately inclining the retort in different directions, all the water is made to flow out of the bulb in which the sulphuret remains. When this is done, the retort is placed in the vertical situation, and its extremity introduced into the tube of glass CD, which must always be under water. A small lighted taper is then to be placed under the bulb. To support the retort in its position, the jar is provided with a wooden cover, in which there is a notch to receive it.

The first impression of the heat dilates the gaseous fluid so much that it descends almost to the bottom of the tube, which is disposed expressly for its reception; otherwise the partial escape would prevent an accurate determination of its change of bulk. But as soon as the sulphuret begins to boil, the water quickly rises, not only in the inferior tube, but likewise in the neck of the retort, notwithstanding the application, and even the increase of the heat.

If the fluid be absolutely pure vital air, the absorption is total. In this case, to prevent the rupture of the vessel by too sudden refrigeration, the ascent of the water must be rendered slower, either by removing the taper, or by increasing the perpendicular height; which will not prevent the absorption from continuing while any gas remains which is proper to support combustion.

If the fluid be common air, or oxygen mixed with any other gas, the quantity of water which has entered the retort must be accurately measured after the cooling. It represents the volume of air absorbed. Care must be taken to inclose the remaining gas under the same pressure, by plunging the retort to the level of the line at which the inclosed water rests, before the orifice is stopped.

This operation of measuring, which is very easy when measuring vessels are at hand, may be habitually performed by a slip of paper pasted on the neck of the retort, upon which divisions are drawn from observation, and which must be covered with varnish to defend it from the action of the water.

EUDOXUS of Gnidus was a celebrated philosopher of the school of Pythagoras. His first preceptor was Archytas, by whom he was instructed in the principles of geometry and philosophy. About the age of twenty-three he came to Athens; and though his patrimony was small, by the generous assistance of Theomedon a physician, he was enabled to attend the schools of the philosophers, particularly that of Plato. The liberality of his friends afterwards supported him during a visit to Egypt, where he was introduced by Agesilaus to king Nectanebis II. and by him to the Egyptian priests. It has been said that he accompanied Plato into Egypt; but this is inconsistent with chronology; for Nectanebis II. reigned in Egypt from the second year of the

hundred and fourth Olympiad, to the second year of the hundred and seventh; and it was before Plato opened his school, that is, before the ninety-eighth Olympiad, about the fortieth year of his age, that he visited Egypt. Eudoxus is highly celebrated by the ancients for his skill in astronomy; but none of his writings on this or any other subject are extant. Aratus, who has described the celestial phenomena in verse, is said to have followed Eudoxus. He flourished about the ninety-seventh Olympiad, and died in the fifty-third year of his age. *Enfield's Hist. of Philosophy.*

EVECTION is used by some astronomers for the libration of the moon, being an inequality in her motion, by which, at or near the quadratures, she is not in a line drawn through the centre of the earth to the sun, as she is at the syzygies, or conjunction and opposition, but makes an angle with that line of about $2^{\circ} 51'$. The motion of the moon about her axis only is equable; which rotation is performed exactly in the same time as she revolves about the earth; for which reason it is that she turns always the same face towards the earth nearly, and would do so exactly, were it not that her monthly motion about the earth, in an elliptic orbit, is not equable; on which account the moon, seen from the earth, appears to librate a little upon her axis, sometimes from east to west, and sometimes from west to east; or some parts in the eastern limb of the moon go backwards and forwards a small space, and some that were conspicuous are hid, and then appear again.

The term *evection* is used by some astronomers to denote that equation of the moon's motion which is proportional to the sine of double the distance of the moon from the sun, diminished by the moon's anomaly. This equation is not yet accurately determined; some state it at $1^{\circ} 30'$, others at $1^{\circ} 16'$, &c. It is the greatest of all the moon's equations, except the equation of the centre. *Hutton's Dictionary.*

EVENLY EVEN NUMBER. See NUMBER, *Encycl.*

EVENLY Odd Number. See NUMBER, *Encycl.*

EVOLVENT, in the higher geometry, a term used by some writers for the involute or curve resulting from the evolution of a curve, in contradistinction to that evolute or curve supposed to be opened or evolved. See EVOLUTE and INVOLUTE, *Suppl.*

EVOLUTE, in the higher geometry, a curve first proposed by Huyghens, and since much studied by mathematicians. It is any curve supposed to be evolved or opened, by having a thread wrapped close upon it, fastened at one end, and beginning to evolve or unwind the thread from the other end, keeping the part evolved or wound off tight stretched; then this end of the thread will describe another curve, called the *involute*. Or the same involute is described the contrary way, by wrapping the thread upon the evolute, keeping it always stretched. For the INVOLUTION and EVOLUTION of Curves, see INVOLUTION in this Supplement.

Imperfect EVOLUTE, a name given by M. Reaumur to a new kind of evolute. The mathematicians had hitherto only considered the perpendiculars let fall from the involute on the convex side of the evolute: but if other lines not perpendicular be drawn upon the same points, provided they be all drawn under the same angle, the effect will still be the same; that is, the oblique lines will all intersect in the curve, and by their intersections form the infinitely small sides of a new curve,

Evection
||
Evolute.

Euphon. to which they would be so many tangents. Such a curve is a kind of evolute, and has its radii; but it is an imperfect one, since the radii are not perpendicular to the first curve or involute.

EUPHON, a musical instrument invented lately by Dr Chladni of Wittenberg, well known by his various publications on philosophical subjects, especially the theory of musical sounds. The euphon consists of forty-two immoveable parallel cylinders of glass of equal length and thickness; but its construction, tone, and the method of playing it, are totally different from those of the harmonica, with which indeed it has nothing in common but the glass. See HARMONICA, *Encycl.*

Dr Chladni gives the following account of his invention. In his 19th year he began to learn to play the harpsichord; and he afterwards read a great many of the principal works on the theory of music, by which he found that the physico-mathematical part of that science was far more defective than other branches of natural philosophy. Being therefore possessed with an idea that his time could not be better employed than in endeavouring to make discoveries in this department, he accordingly tried various experiments on the vibrations of strings and the different kinds of vibration in cylindrical pieces of wood, first discovered, through calculation, by the elder Euler; and found, that though a great deal had been said on the nature of these elastic bodies, yet the manner of vibration and the proportion of tones in other elastic bodies, which do not proceed, as in the former, in straight lines, but depend on the vibration of whole surfaces, were totally unknown, and that the little which had been written on that subject, by some authors, did not correspond with nature. He had already long remarked, that every plate of glass or metal emitted various tones according as it was held and struck in different places; and he was desirous to discover the cause of this difference, which no one had ever examined. He fixed in a vice the axle of a brass plate which belonged to a polishing machine, and found, that by drawing the bow of a violin over it, he produced very different tones, which were stronger and of longer duration than those obtained merely by striking it.

The observation, that not only strings but also other elastic bodies may be made to produce sounds by drawing a violin bow over them, Dr Chladni does not give as a discovery of his own; as the so called iron violin has been long known, and as he had read of an instrument constructed in Italy*, where glass or metal bells were made to sound by means of two or more violin bows drawn over them. But the idea of employing this instrument to examine vibrating tones was first entertained by himself. Having accurately remarked the tones produced by the abovementioned metal plate, he found that they gave a progression which corresponded with the squares of 2, 3, 4, &c.

Not long before he had read, in the Transactions of the Royal Society of Göttingen, the observations of Mr Lichtenberg on the phenomena produced by strewing pounded resin over a glass plate or cake of resin, and he repeated many of his experiments. This led him to the idea that, perhaps, the various vibratory movements of such a plate would be discovered by a diversity of phenomena, if he strewed over it sand or any thing of the like kind. By this experiment there was

produced a star-formed figure; and the author, having continued his researches, published the result of them in a work entitled, Discoveries respecting the Theory of Sound, printed at Leipzig in 1787.

Whilst he was employed in these investigations, he resolved to invent a new musical instrument; and he began to consider whether it might not be possible by rubbing glass tubes in a straight line, with the wet fingers, to produce sounds in the same manner as is done in the harmonica by rubbing them circularly. That glass tubes, like those in his euphon, would not merely by such rubbing emit any tones, he had long known by theory and experience; and he therefore applied himself to the solution of the difficult question, in what manner the instrument ought to be constructed to answer the intended purpose? After various fruitless attempts for a year and a half, during which his imagination was so full of the idea, that sometimes in his dreams he thought he saw the instrument and heard its tones, that is, like those of the harmonica, but with more distinctness and less confusion, he at length, in a state between sleeping and waking, obtained a solution of the problem which had given so much employment to his thoughts. On the second of June 1789, being tired with walking, he sat down on a chair, about nine in the evening, to enjoy a short slumber; but scarcely had he closed his eyes when the image of an instrument, such as he wished for, seemed to present itself before him, and terrified him so much that he awoke as if he had been struck by an electric shock. He immediately started up in a kind of enthusiasm; and made a series of experiments which convinced him that what he had seen was perfectly right, and that he had it now in his power to carry his design into execution. He made his experiments and constructed his first instrument in so private a manner that no person knew any thing of them. On the 8th of March 1790 his first instrument of this kind was completed; and in a few days he was able to play on it some easy pieces of music. It was now necessary to give to this instrument, as it was entirely new, a new name; and that of *euphon*, which signifies an instrument that has a pleasant sound, appeared to him the most proper.

It was not, however, brought to perfection at once, for he made a second instrument which was an improvement of the first, and a third which was an improvement of the second. In sound, indeed, and particularly in the higher tones, the first was equal to either of the other two; but the construction was deficient in strength, so that every week some hours were necessary to keep it in proper repair; and it was impossible to convey it the distance of a mile without almost totally destroying it. Dr Chladni also, for want of better tubes, employed those used for thermometers, and marked the whole and half tones by a coating of sealing wax on the under side; but as the wax, owing to the moisture and vibration, often cracked and flew off, it was attended with danger to the eyes. It was therefore extremely difficult to give to the construction of the instrument sufficient strength; but this the inventor at length accomplished, so that his new euphon cannot be injured or put out of tune either by playing or by carriage. The third instrument was somewhat different from the first and second; as the fore part, which in the two former rose upwards with an oblique angle, stood

*In all probability the Harmonica of the Abbe Mazzuchi.

Euphon,
Euphorbia.

at right angles, so that it could be transported with ease in a particular carriage made for that purpose. Instead of the thermometer tubes used in the first, the Doctor now employs tubes of different colours. In the second instrument those for the whole tones were of dark green glass; but he used for the half tones, in both, a milk white kind of glass. In a word, the euphon has some resemblance to a small writing-desk. When opened, the abovementioned glass tubes, of the thickness of the barrel of a quill and about 16 inches long, are seen in a horizontal position. They are wetted with water, by means of a sponge, and stroked with the wet fingers in the direction of their length, so that the increase of the tone depends merely on the stronger or weaker pressure, and the slower or quicker movement of the fingers. The number of tubes at present is forty-two. In the back part there is a perpendicular sounding-board divided in the middle, through which the tubes pass. It appears therefore that the euphon ought not to be considered as an altered or improved harmonica, but as a totally new and different instrument. In regard to sweetness of sound, it approaches very near to the harmonica; but it has several advantages which no unprejudiced person, who examines both instruments, will deny.

1. It is simpler, both in regard to its construction and the movement necessary to produce the sound, as neither turning nor stamping is required, but merely the movement of the finger. 2. It produces its sound speedier; so that as soon as it is touched you may have the tone as full as the instrument is capable of giving it; whereas, in the harmonica, the tones, particularly the lower ones, must be made to increase gradually. 3. It has more distinctness in quick passages, because the tones do not resound so long as in the harmonica, where the sound of one low tone is often heard when you wish only to hear the following tone. 4. The unison is purer than is generally the case in the harmonica, where it is difficult to have perfect glasses, which in every part give like tones with mathematical exactness. It is however as difficult to be tuned as the harmonica. 5. It does not affect the nerves of the performer; for a person scarcely feels a weak agitation in the fingers; whereas in the harmonica, particularly in concords of the lower notes, the agitation extends to the arms, and even through the whole body of the performer. 6. The expence of this instrument will be much less in future than that of the harmonica. 7. When one of the tubes breaks, or any other part is deranged, it can be soon repaired, and at very little expence; whereas, when one of the glasses of the harmonica breaks, it requires much time, and is very difficult to procure another capable of giving the same tone as the former, and which will correspond sufficiently with the series of the rest.

EUPHORBIA (See *Encycl.*). Of this plant three new species were discovered by Le Vaillant during his last travels into the interior parts of Africa. The first, which he calls the CUCUMBER-EUPHORBIA, adheres to the earth no otherwise than by a few slender roots. It rises to the height of nine or ten inches only; and exactly resembles a cucumber, of which it has the bent shape. It contains abundance of milky juice, which appeared to him as caustic as that of the great euphorbia. Its colour, which is a yellowish-green, tinted with a beautiful shade of violet towards the root, gives it a

Plate
XXVIII.
fig. 1.

very attractive appearance: but woe betide the man who should be tempted to eat of it! as it is a virulent poison. The second, to which he gave the name of the MELON-RIBBED EUPHORBIA, does not rise more than three or four inches from the ground, to which it adheres by a collection of fibrous roots, issuing from several tubercles disposed in the manner of a crown. The stem forms a flatted globe excavated at the summit, and has ribs like the apple which in France is called *calville blanche*. These ribs are elevated, thick, and convex, have a greenish colour, and are marked with brown transversal bands. From the summit of the ribs issue several little tufts of pedunculate flowers. The third he called the CATERPILLAR-EUPHORBIA, because when he first found it, he thought he perceived on it several beautiful caterpillars. The description of it in a few words is as follows: From a very large tuberous root, which here and there throws out a few thready fibres, issue several stalks almost of the length of the finger: they creep along the ground, are twisted, woody, destitute of leaves, and furnished with several rows of round tubercles, each guarded by two prickles.

All these kinds of euphorbia are to be dreaded, the last two in particular; because being low and mixed with the herbage like mushrooms, animals, as they feed, run the risk of eating them with their pasture. Our author confirms the account which has been given in the *Encyclopædia* of the savages poisoning the reservoirs of water with this plant, in order to procure the game which shall drink of it. To effect the death of the animal, it is necessary that the poison reach the blood and mingle with it. Yet, unconceivable as it may be, the animal, though poisoned, is not the less wholesome food, as our author says he has experienced. However great may be the proportion of euphorbia thrown into a pond of water, he is persuaded that it never diffuses itself through the whole mass. It is his opinion, that the poison is a resinous juice, which, being from its nature incapable of combining with water, swims on the surface, and there forms a shining greenish oil, which with a little attention may be discerned by the naked eye when the surface is smooth. I tried (says he) the qualities of this oil on myself, taking with a straw, from the surface of the basin, a single drop, which I put upon my tongue; and it gave me that kind of burning pain which a caustic occasions. I then took up some water from the reservoir in the hollow of my hand, and blowing off the oily fluid which swam on the surface, I dipped the end of my tongue into the remainder, but could not perceive in it the slightest taste different from that of water itself. He seems to think that milk is an antidote to the poison of euphorbia; because he squeezed some of the juice into a basin of milk and gave it to an ape, which swallowed part of it without the least injury. He confesses, however, that the dose was trifling.

EUSTYLE, is the best manner of placing columns, with regard to their distance; which, according to Vitruvius, should be four modules, or two diameters and a quarter.

EXCENTRIC, or EXCENTRIC CIRCLE, in the ancient Ptolomaic astronomy, was the very orbit of the planet itself, which it was supposed to describe about the earth, and which was conceived excentric with it; called also the deferent.

Instead.

Euphorbia
||
Excentric.
Fig. 2.

Fig. 3.

Excentric
||
Expectation.

Instead of these excentric circles round the earth, the moderns make the planets describe elliptic orbits about the sun; which accounts for all the irregularities of their motions, and their various distances from the earth, &c. more justly and naturally.

EXCENTRIC, or *Excentric Circle*, in the new astronomy, is the circle described from the centre of the orbit of a planet, with half the greatest axis as a radius; or it is the circle that circumscribes the elliptic orbit of the planet.

EXCHANGE. See *Encycl.* under that word, and likewise under *BILLS of Exchange*, where the antiquity of such bills, especially among the Chinese, is mentioned. In Professor Beckmann's *History of Inventions* the reader will find an ordinance of the year 1394 concerning the acceptance of bills of exchange, and also copies of two bills of the year 1404, which sufficiently prove that the method of transacting business by bills of exchange was fully established in Europe so early as the fourteenth century; and that the present form and terms were even then used. The ordinance, which was issued by the city of Barcelona, decreed that bills of exchange should be accepted within twenty-four hours after they were presented, and that the acceptance should be written on the back of the bill.

But there are questions relating to bills of exchange of much greater importance than their antiquity; and these questions are not yet decided. For instance, Ought a bill of exchange to be considered by the law merely as a *deposit* belonging to the drawer, and successively confided to the remitees? or should it be considered as transferable *property*, at all times absolutely vested in the holder, whose neglect therefore, when it vitiates the value, falls wholly on himself?

In a work published 1798 by Professor Busch of Hamburg, entitled, *Additions to the Theoretical and Practical Delineation of Commerce* (A), the reader will find some arguments, which, to say the least of them, are certainly plausible, to prove that bills of exchange ought to be at all times considered as the absolute property of the holder. This theory is then applied to the difficult and still unsettled case of the holder of a bill having many indorsements, where the drawer, drawee, and early indorsers, have all failed. It is evident that, if the holder proves under each bankruptcy the whole amount of the bill, he will receive much more than his due. May he make his election where to prove the whole demand, and where to prove the residue? or ought he not (which seems most equitable) to be compelled to prove his debt against his immediate predecessor only?—the assignees of that predecessor proving in their turn, in like manner (each party once only), back to the drawer. 'This is a case of great importance to discounters, and the reader will find some judicious observations on it in the Professor's work.

EXEGESIS, or EXEGETICA, in algebra, is the finding, either in numbers or lines, the roots of the equation of a problem, according as the problem is either numeral or geometrical.

EXPECTATION OF LIFE, in the doctrine of life annuities, is the share, or number of years of life, which

a person of a given age may, upon an equality of chance, expect to enjoy.

By the expectation or share of life, says Mr Simpson (*Select Exercises*, p. 273), is not here to be understood that particular period which a person hath an equal chance of surviving; this last being a different and more simple consideration. The expectation of a life, to put it in the most familiar light, may be taken as the number of years at which the purchase of an annuity, granted upon it, without discount of money, ought to be valued. Which number of years will differ more or less from the period abovementioned, according to the different degrees of mortality to which the several stages of life are incident. Thus it is much more than an equal chance, according to the table of the probability of the duration of life which the same author has given us, that an infant, just come into the world, arrives not to the age of ten years; yet the expectation or share of life due to it, upon an average, is near twenty years. The reason of which wide difference is the great excess of the probability of mortality in the first tender years of life, above that respecting the more mature and stronger ages. Indeed if the numbers that die at every age were to be the same, the two quantities above specified would also be equal; but when the said numbers become continually less and less, the expectation must of consequence be the greater of the two.

EXPONENTIAL CALCULUS, the method of differencing, or finding the fluxions of exponential quantities, and of summing up those differences, or finding their fluents.

EXPONENTIAL *Curve*, is that whose nature is defined or expressed by an exponential equation; as the curve denoted by $a^x = y$, or by $x^x = y$.

EXPONENTIAL *Equation*, is one in which is contained an exponential quantity: as the equation $a^x = b$, or $x^x = a b$, &c.

EXPONENTIAL *Quantity*, is that whose power is a variable quantity; as the expression a^x , or x^x . Exponential quantities are of several degrees and orders according to the number of exponents or powers, one over another.

EXTRA-CONSTELLARY STARS, such as are not properly included in any constellation.

EXTRA-MUNDANE *Space*, is the infinite, empty, void space, which is by some supposed to be extended beyond the bounds of the universe, and consequently 'in which there is really nothing at all. The phrase *extramundane space* has been so long in use among our best writers, that it is now impossible to banish it from the language; and yet it has been the source of some extravagant mistakes. Many philosophers consider space as something *real*, distinct both from body and mind; and no less a man than Dr Clarke considered it as an attribute of the Deity. Yet we think nothing more evident, than that if body had never existed, space would never have been thought of; and if this be so, extramundane space, instead of denoting any *real* thing, or attribute infinitely extended, can mean nothing more than the *possibility* of enlarging the corporeal universe, however widely extended it may be. See METAPHYSICS, *Encycl.* Part II. ch. iv.

Exponential,
Extra-Con-
stellary.

EX

(A) Professor Busch published in 1792 a work entitled *A Theoretical and Practical Delineation of Commerce*.

Extrados,
Extremes.

EXTRADOS, the outside of an arch of a bridge, vault, &c. See **ARCH** in this *Supplement*.

EXTREMES CONJUNCT, and *Extremes Disjunct*, in spherical trigonometry, are, the former the two circular parts that lie next the assumed middle part; and the latter are the two that lie remote from the middle part. These were terms applied by Lord Napier in his universal theorem for resolving all right-angled and quadrantal spherical triangles, and published in his *Logarithmorum Canonis Descriptio*, ann. 1614. In this theorem, Napier condenses into one rule, in two parts, the rules for all the cases of right angled spherical triangles,

which had been separately demonstrated by Pitiscus, Lansbergius, Copernicus, Regiomontanus, and others. In this theorem, neglecting the right angle, Napier calls the other five parts circular parts, which are, the two legs about the right angle, and the complements of the other three, viz. of the hypotenuse, and the two oblique angles. Then taking any three of these five parts, one of them will be in the middle between the other two, and these two are the extremes conjunct when they are immediately adjacent to that middle part, or they are the extremes disjunct when they are each separated from the middle one by another part.

Extremes.

F.

Face,
Falconry.

FACE or **FAÇADE**, in architecture, is sometimes used for the front or outward part of a building, which immediately presents itself to the eye; or the side where the chief entrance is, or next the street, &c.

FALCONRY, is a species of sport, about the antiquity of which there has been some dispute. Under the word **HAWKING**, *Encycl.* we have deduced what we thought sufficient evidence of its being practised among the Thracians, and likewise among the Britons before the invasion of this island by the Romans. Flavius Blondus, however, and Laurentius Valla, both writers of the 15th century, and the latter, one of the most learned men of his time, affirm that no nation or people were accustomed to catch either land or water fowls with any rapacious bird trained for the purpose.

We were pleased to see our own opinion, so different from this, completely established by the learned labours of Professor Beckmann. So early (says he) as the time of Ctesias (and he refers to the page and edition of his author) hares and foxes were hunted in India by means of rapacious birds. The account of Aristotle*, however, is still more to the purpose, and more worthy of notice. "In Thrace (says he) the men go out to catch birds with hawks. The men beat the reeds and bushes which grow in marshy places, in order to raise the small birds, which the hawks pursue and drive to the ground, where the fowlers kill them with poles." The same account is to be found in another book ascribed also to Aristotle; and which appears, at any rate, to be the work of an author not much younger. Respecting Thrace, which is situated above Amphipolis, a wonderful thing is told, which might appear incredible to those who had never heard it before. It is said that boys go out into the fields, and pursue birds by the assistance of hawks. When they have found a place convenient for their purpose, they call the hawks by their names, which immediately appear as soon as they hear their voices, and chase the birds into the bushes, where the boys knock them down with sticks and seize them. What is still more wonderful, when these hawks lay hold of any birds themselves, they throw them to the fowlers; but the boys, in return, give

* *Hist Animal*, lib. ix. cap. 6.

them some share of the prey. *De mirabilibus auscultat.* Falconry. cap. 128.

In this passage, there are two additions which render the circumstance still more remarkable. The first is, that the falcons appeared when called by their names; and the second, that of their own accord they brought to the fowlers whatever they caught themselves. Nothing is here wanting but the spaniel employed to find out game, the hood which is put upon the head of the hawk while it stands on the hand, and the thong used for holding it, to form a short description of falconry as still practised. Our falconers, when they have taken the bird from the hawk, give him, in return, a small share of it; and in the like manner the Thracian hawks receive some part of their booty.

Other writers after Aristotle, such as Antigonus, Ælian, Pliny, and Phile, have also given an account of this method of fowling. Ælian, who seldom relates any thing without some alteration or addition, says, that in Thrace nets were used, into which the birds were driven by the hawks; and in this he is followed by the poet Phile. Ælian, also, in another place describes a manner of hunting with hawks in India, which, as we are told by several travellers, is still practised in Persia, where it is well understood, and by other eastern nations.

The Indians (says he) hunt hares and foxes in the following manner: They do not employ dogs, but eagles, crows, and, above all, kites, which they catch when young, and train for that purpose. They let loose a tame hare or fox, with a piece of flesh fastened to it, and suffer these birds to fly after it, in order to seize the flesh, which they are fond of, and which, on their return, they receive as the reward of their labour. When thus instructed to pursue their prey, they are sent after wild foxes and hares in the mountains; these they follow in hopes of obtaining their usual food, and soon catch them and bring them back to their masters, as we are informed by Ctesias. Instead of the flesh, however, which was fastened to the tame animals, they receive as food the entrails of the wild ones which they have caught.

It seems, therefore, that the Greeks received from India

dia and Thrace the first information respecting the method of fowling with birds of prey; but it does not appear that this practice was introduced among them at a very early period. In Italy, however, it must have been very common, for Martial and Apuleius speak of it as a thing every where known: the former calls a hawk the fowler's servant.

The Professor traces the history of this art with great learning down to the present time. It was carried to the highest perfection at the principal courts of Europe (he says) in the 12th century, when the ladies kept hawks, which were as much fondled by those who wished to gain their favour as lap dogs are at present. Among the oldest writers on falconry, as an art, he reckons Demetrius, who about the year 1270 was physician to the Emperor Michael Paleologus. His book, written in Greek, was first printed at Paris in 1612 with a Latin translation; but its precepts (says our author) would be thought of very little value at present. For an account of the modern art of FALCONRY, see *Encyclopædia*.

FALK (John Peter), known to the world as one of the scientific travellers employed by the late Empress of Russia to explore her vast dominions, was born in Westrogothia, a province in Sweden, about the year 1727. He studied medicine in the university of Upsal, and went through a course of botany under the celebrated Linnæus, to whose son he was tutor. He publicly defended the dissertation (A) which that famous botanist had composed on a new species of plants, which he called *astromeria*.

In the year 1760, he was so deeply affected with depression of spirits, that M. de Linné, in the view of obliging him to take exercise and dissipation, sent him to travel over the island of Gothland, to make a collection of the plants it produces, and the various kinds of corals and corallines which the sea leaves on its shores. This voyage was attended with no diminution of his distemper, which found a continual supply of aliment in a sanguine melancholy temperament, in a too sedentary way of life, and in the bad state of his finances.

Professor Forskael having left Upsal for Copenhagen in 1760, Falk followed him thither; in the design of applying, by the advice of M. de Linné, to be appointed assistant to M. Forskael in his famous journey thro' Arabia; but notwithstanding all the pains that M. Ceder, and several other men of literary reputation at Copenhagen, took in his behalf, his application failed, as the society that were to go on that important expedition was already formed. Obligated, with much discontent, to return, he herborized as he travelled, and enriched the Flora Suecica with several new discoveries.

A man in office at St Petersburg having written to M. Linné to send him a director for his cabinet of natural history, M. Falk accepted the post, which led him to the chair of professor of botany at the apothecaries garden at St Petersburg, a place that had been long vacant. His hypochondriac complaint still continued to torment him. When the Imperial Academy of Sciences was preparing in 1768 the plan of its learned expeditions, it took M. Falk into its service, though his health was uncertain. He was recalled in 1771; but

having got only to Kafan in 1773, he there obtained permission to go and use the baths of Kisliar, from which he returned again to Kafan at the end of the year, with his health apparently better.

But his disease soon returned with redoubled violence. From the month of December 1773 he had never quitted his bed, nor taken any other nourishment than bread dried in the Swedish manner (*knækebrød*), of which he scarcely took once a day some mouthfuls dipped in tea. At first he received the visits of a few friends; but afterwards denied himself to them, and was reduced to the strictest solitude. When M. Georgi, member of the society of natural history at Berlin, who had been destined to assist and relieve the professor in the duties of his expedition, went to see him on this occasion, nothing seemed left of him but a skeleton of a wild and terrifying aspect. The few words he drew from him consisted in complaints, occasioned by a host of diseases which kept his body in torture, and threw him into the most cruel sleeplessness. The last evening M. Georgi kept him company till midnight. He spoke little, and said nothing that could give reason to suspect the design he was meditating. His hunter, and at the same time his trusty servant, offered to sit up with him the night; but he could not be persuaded to consent.

M. Georgi being requested the next day, March 31, to come to the lodging of the unfortunate gentleman, he found him lying before his bed, covered with blood; beside him lay a razor, with which he had given himself a slight wound in the throat, the fatal pistol, and a powder-horn; all together presenting a tremendous spectacle. He had put the muzzle of the pistol against his throat, and, resting the pommel upon his bed, he discharged the contents in such a manner, that the ball, having gone through his head, had stuck in the ceiling. His soldier had seen him still sitting up in his bed at four o'clock, at which time he usually fell into a short slumber. In his chamber was found a note written the evening before, betraying throughout the distracted state of his mind, but nothing declaratory of his design, or that was of any importance.

M. Falk, like all hypochondriac persons, was not very communicative, and on certain occasions was distrustful. But, at the same time, he was of a sedate temper, complaisant, and upright, which made it a very easy matter to bear with him, and secure to him the indulgence of all his acquaintance. His extreme sobriety had enabled him to make some savings from his pay, though he was very beneficent; it was not, therefore, indigence that drove him to this act of violence. He was of a cold constitution, preferring solitude and quiet to society, to the company of his friends, and to ordinary amusements, which yet he did not shun, except in the latter period of his life. As to religion, he shewed on all occasions more respect for it than any strong effusions of zeal. It was solely to be ascribed to the violence of his distemper, and the weakness of mind which it brought on, that led him to put a period to his days. The fate of this unfortunate scholar was generally and justly lamented.

His papers were found in the greatest disorder. They contain,

(A) In the collection known under the title of *Linnei Amenitates Academica*.

Farmer.

contain, however, very useful and important relations. He particularly made it his business to inquire about the Kirguises, and other Tartarian nations; and as he frequently remained for the space of nine months together in the same place, he was enabled to procure satisfactory notions concerning the objects of his investigations. The Imperial Academy, in 1774, appointed Professor Laxmann to arrange his manuscripts in order for publication; which was done accordingly.

FARMER (Richard, D. D.), so well known as one of the commentators on Shakespeare, was a man of such pleasing, though singular manners, that we regret the very imperfect account which we must give of his life. One of us, who had the pleasure of being a little known to him, has been so much delighted with the natural ease and pleasantry of his conversation, that we made all the inquiries which we judged requisite to enable us to draw up such a biographical sketch of this agreeable man as might be acceptable to our readers, and not unworthy of his character; but these inquiries were made in vain. Those to whom we applied knew little more of the incidents of his life than what we had previously found in a miscellany, of which the writers seem to consider it as a principle of duty to vilify the character of every person who, like Dr Farmer, is the friend of order, and the enemy of sudden or rapid innovations. To that miscellany, therefore, we must be beholden for many facts; but we shall certainly copy none of its malevolence.

Dr Farmer was born at Leicester 1735; but what was the station of his father we have not learned. Of his school education he received part, perhaps the whole, in his native town; and from school he was removed to the university of Cambridge, where he devoted himself chiefly to classical learning and the belles lettres. In 1757 he was admitted to the degree of bachelor of arts; in 1760 to that of master of arts; a bachelor of divinity in 1767, and a doctor of divinity in 1775; in which year he was also elected master of Emanuel on the decease of Dr Richardson, and principal librarian on the decease of Dr Barnardiston.

The disturbances in America having by this time become serious, the university of Cambridge, with numberless other loyal bodies, voted an address to the king, approving of the measures adopted by government to reduce the factious colonists to their duty. The address, however, was not carried unanimously. It was, of course, opposed by JEBB, so well known for his free opinions in politics and religion, and by some others, of whom one man, a member of the CAPUT, carried his opposition so far, as actually to refuse the key of the place which contained the seal necessary on such occasions. In this emergency, Dr Farmer, who was then vice-chancellor, is said to have forced open the door with a sledge-hammer; an exploit which his democratical biographers affect to ridicule, by calling it *his courtly zeal*, and the occasion of all his subsequent preferments.

If it be indeed true that he broke the door in pieces with his own hands, his conduct must be acknowledged to have been not very decorous; but if the office which he filled be taken into consideration, we apprehend it would be as difficult to prove that conduct essentially wrong, as to vindicate the obstinate arrogance of him who occasioned it. The seal was the property of the

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university, of which this outrageous supporter of the bill of rights was but an individual member. The university had resolved that it should be employed for a certain purpose, which it was the duty of the vice-chancellor to carry into effect; and since the seal was refused to him, he had no alternative but to get possession of it by force. We hope, however, that he employed a servant to break the door; and, indeed, as vice-chancellor, he must have had so many servants at his command, that it is not conceivable he would wield the sledge hammer himself.

Some time after this he was made a prebendary of Canterbury, we believe through the recommendation of Lord North, then premier; and it was at Canterbury that the writer of this sketch had the happiness of being introduced to him, and witnessing his hospitality. After enjoying his prebend for several years, he resigned it on being preferred, by the present premier, to a residentiaryship of St Paul's; and we have reason to believe that he declined a bishopric, which was offered to him as a reward for the constitutional principles which he was at pains to propagate, not only in his college, but, as far as his influence went, through the whole university.

It has been said that the delights of the pipe and the bottle in Emanuel parlour outweighed, in his estimation, the dazzling splendor of the mitre; but he had other and better reasons for preferring a private to a public station. In early life, at least before he was advanced in years, he had felt the power of love, and had suffered such a disappointment as sunk deep in his mind, and for a time threatened his understanding. From that period, though he retained his faculties entire, he acquired some peculiarities of manner, of which he was so far conscious as to be sensible that they would hardly become the character of a bishop: being likewise strongly attached to dramatic entertainments, which, if we mistake not, the English bishops never witness, and delighting in clubs, where he could have rational conversation without state or ceremony of any kind—he very wisely preferred his residentiaryship to the highest dignity in the church. At the time of his death, which happened in the autumn of 1797, he was a fellow of the Royal and Antiquarian Societies, master of Emanuel college, principal librarian of the public library in the university, one of the canons residentiary of St Paul's, chancellor of the diocese of Lichfield and Coventry, and prebendary of Worcester.

Though a good classical scholar, Dr Farmer has been celebrated only for that kind of literature which is connected with the English drama; and having a strong predilection for old English writers, he ranked high among the commentators upon Shakespeare. His 'Essay upon the Learning of Shakespeare,' dedicated to Mr Cradock, the intelligent resident of Gumley-Hall in Leicestershire, has passed through several editions. This essay was, in fact, the first foundation of his fame, which an unconquerable indolence prevented him from carrying to that height to which the exercise of his literary talents could not have failed to raise it. So great indeed was his love of ease, that after having announced for subscriptions a history of Leicestershire, and actually begun to print it, rather than submit to the fatigue of carrying it through the press, he returned the subscriptions, and presented the MSS. and plates to Mr Nichols,

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Nichols, the respectable printer of the Gentleman's Magazine, who has since carried on the history with a degree of spirit, ability, and industry, perhaps unprecedented in this department of literature.

Indolence and the love of ease were indeed the Doctor's chief characteristics; and to them, with the dis-appointment already mentioned, may be attributed a want of propriety in his external appearance, and in the usual forms of behaviour belonging to his station. The prevailing features of his character distinguished themselves by several oddities: There were three things, it was said, which the master of Emanuel loved, *viz.* old port, old clothes, and old books; and three things which no one could persuade him to perform, *viz.* to rise in the morning, to go to bed at night, and to settle an account. When in Cambridge, if an old house were pulled down, the master of Emanuel was always there in an old blue great coat, and a rusty hat. When in London, he was sure to be found in the same garb at an old book-stall, or standing at the corner of a dirty lane, poring through his glass at an old play-bill.

This character is not drawn by a friendly pencil; but it is nevertheless not unjust. His inattention to the common decencies of dress and behaviour was notorious, inasmuch that, in the company of strangers, the eccentricity of his appearance and of his manners made him sometimes be taken for a person half crazed. The writer of this sketch saw him one morning at Canterbury dressed in stockings of unbleached thread, brown breeches, and a wig not worth a shilling; and when a brother prebendary of his, remarkable for elegance of manners, and propriety of dress, put him in mind that they were to attend on the archbishop, Dr Farmer replied, that it had totally escaped him; but he went home, and dressed himself like a clergyman. That he sat late reading, and occasionally drinking brandy and water, cannot be denied; and it is literally true, that he could not easily be prevailed upon to settle his accounts. His accounts with some of his pupils, when tutor of his college, were never settled to the day of his death; and the young gentlemen not unfrequently took advantage of this unconquerable indolence to borrow of him considerable sums, well knowing that there was little chance of a demand being ever made upon their parents. One gentleman, in particular, told a friend of ours, who was himself a pensioner of Emanuel, that when he left that college, he was near fifty pounds in debt to Dr Farmer; "a debt (said he) which I would have scrupulously paid, but, after repeated solicitations, I could get no bill from him."

Having been a warm partizan of government during the American war, it will readily be believed that Dr Farmer was the determined enemy of levellers and anar-chists. He was such a whig as those who placed King William on the throne; and of course deemed a violent tory by our present republicans, of whom, to say the truth, he could hardly speak with temper. By his enemies he is admitted to have been a man of generosity. As he obtained money easily, so he parted with it easily. Whilst he was always ready to relieve distress, his bounty was frequently bestowed on the patronage of learned men and learned publications. He was, accordingly, a favourite with all good men who knew him. In his own college he was adored; in the university he had, for many years, more influence than any other

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individual; and, with all his eccentricities, his death was a loss to that learned body, which, in the opinion of some of its members, will not soon be made up.

A short time before his death, his character was thus justly and ably drawn by the celebrated Dr Parr:

"Of any undue partiality towards the master of Emanuel College, I shall not be suspected by those persons who know how little his sentiments accord with mine, upon some ecclesiastical, and many political matters. From rooted principle and ancient habit he is a tory; I am a whig; and we have both of us too much confidence in each other, and too much respect for ourselves, to dissemble what we think, upon any grounds, or to any extent. Let me then do him the justice which, I am sure, that he will ever be ready to do to me. His knowledge is various, extensive, and recondite. With much seeming negligence, and perhaps, in later years, some real relaxation, he understands more, and remembers more, about common and uncommon subjects of literature, than many of those who would be thought to read all the day and meditate half the night. In quickness of apprehension, and acuteness of discrimination, I have not often seen his equal. Through many a convivial hour have I been charmed by his vivacity; and upon his genius I have reflected, in many a serious moment, with pleasure, with admiration, but not without regret that he has never concentrated and exerted all the great powers of his mind in some great work, upon some great subject. Of his liberality in patronising learned men I could point out numerous instances. Without the smallest propensities to avarice, he possesses a large income; and, without the mean submission of dependence, he is risen to a high station. His ambition, if he has any, is without insolence; his munificence is without ostentation; his wit is without acrimony; and his learning without pedantry."

FASCINATION, the art of bewitching, enchantment, an unseen inexplicable influence. Under the title SERPENS (*Encycl.* n^o 22.) we have mentioned several instances of the fascinating power of the rattlesnake, which were related by men of character, and certainly gained some degree of credit among men of science. In Vaillant's *New Travels into the Interior Parts of Africa*, an account is given of similar instances of fascination by African servants, some of them witnessed by himself, and others reported to him by men of veracity.

On the confines of the European colony, at a place called *Swart-land*, our traveller saw a shrike on the branch of a tree, tremble as if in convulsions, whilst it uttered the most piercing cries of distress. Closer attention led him to discover upon the next branch of the same tree a large serpent, that, with stretched-out neck, and fiery eyes, though perfectly still, was gazing on the poor animal. He shot the serpent; but, in the mean time, the bird had died. Having measured the distance between the place where the shrike was seen in convulsions and that occupied by the serpent when it was shot, he found it to be three feet and a half; which convinced him and his attendants that the bird had not died either from the bite or the poison of its enemy. Indeed he stripped it before the whole company, and made them observe that it was untouched, and had not received the slightest wound.—In another district of Africa, during the course of the same travels, he

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saw a small mouse die in convulsions, occasioned by the fascinating power of a serpent, at the distance of two yards from it; and when he consulted his Hottentots upon this incident, they expressed, he says, no sort of astonishment, but assured him that the serpent had the faculty of attracting and fascinating such animals as it wished to devour.

We have already had occasion to remark how regardless this author is of inconsistencies in his narrative; and we perceive something like an inconsistency in the narratives before us. Though his Hottentots expressed no surprise at the fascination of the mouse, and declared that nothing was more common, he says expressly, that to those who witnessed the fascination of the shrike, the fact appeared so extraordinary, that they could hardly believe it, even after they had seen it.

The most wonderful instance of fascination which we have anywhere met with, was that of a Captain in the Dutch service at the Cape, who, after assuring our traveller that it is an event which happens very frequently, proceeded thus: "My testimony ought to have the more weight, as I had once nearly become myself a victim to this fascination." While in garrison at Ceylon, and amusing myself, like you, in hunting in a marsh, I was, in the course of my sport, suddenly seized with a convulsive and involuntary trembling, differing from any thing I had ever experienced, and at the same time was strongly attracted, and in spite of myself, to a particular spot of the marsh. Directing my eyes to this spot, I beheld, with feelings of horror, a serpent of an enormous size, whose look instantly pierced me. Having, however, not yet lost all power of motion, I embraced the opportunity before it was too late, and saluted the reptile with the contents of my fusée. The report was a talisman that broke the charm. All at once, as if by a miracle, my convulsion ceased; I felt myself able to fly; and the only inconvenience of this extraordinary adventure was a cold sweat, which was doubtless the effect of my fear, and of the violent agitation my senses had undergone."

This instance of fascination differs in one very material circumstance from the two somewhat similar instances mentioned in the *Encyclopædia*. In both these, the eyes of the persons fascinated were fixed on the eyes of the snake; but here the Dutch Captain was strongly attracted towards the serpent before he saw, or even suspected, that so formidable an enemy was in his neighbourhood. If the story therefore be true, the effect which he describes could not possibly have been the effect of fear, but of some unseen influence on his whole nervous system.

The subject has of late attracted the attention of men of science, whose local situation gives them an opportunity of making experiments upon different serpents, with a view to ascertain whether they really possess or not this most unaccountable of all powers. In the year 1796 was printed at Philadelphia, a *Memoir concerning the Fascinating Faculty which has been ascribed to the Rattle-snake, and other American Serpents*, by Benjamin Smith Barton, M. D. Professor of natural history and botany in the university of Pennsylvania. In this memoir, the manner in which the fascinating power is supposed to be exerted is thus stated by the ingenious professor:

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"The snake, whatever its species may be, lying at the bottom of the tree or bush upon which the bird or squirrel sits, fixes its eyes upon the animal it designs to fascinate or enchant. No sooner is this done, than the unhappy animal is unable to make its escape. It now begins to utter a most piteous cry, which is well known by those who hear it, and understand the whole machinery of the business, to be the cry of a creature enchanted. If it is a squirrel, it runs up the tree for a short distance, comes down again, then runs up, and, lastly, comes lower down. 'On that occasion (says an honest, but rather credulous writer*), it has been observed, that the squirrel always goes down more than it goes up.' 'The snake still continues at the root of the tree, with its eyes fixed on the squirrel, with which its attention is so entirely taken up, that a person accidentally approaching, may make a considerable noise without the snake's so much as turning about. The squirrel, as before mentioned, comes always lower, and at last leaps down to the snake, whose mouth is already wide open for its reception. 'The poor little animal then, with a piteous cry, runs into the snake's jaws, and is swallowed at once, if it be not too big; but if its size will not allow it to be swallowed at once, the snake licks it several times with its tongue, and smoothes it, and by that means makes it fit for swallowing.'"

* Professor Peter Kalm.

From Dr Barton's memoir, it appears that the North American Indians are by no means of one opinion respecting the fascinating power of the rattle-snake. Some intelligent friends of his, well acquainted with the manners, religious opinions, and superstitious prejudices of those people, informed him, that though they had often heard the Indians speak of the ingenuity of these reptiles in catching birds, squirrels, &c. they did not recollect having ever heard them say that snakes charm birds. On the other hand, however, a Mohegan Indian told the Doctor himself, that the Indians are of opinion, that the rattle-snake can charm, or bewitch, squirrels and birds, and that it does this with its rattle, which it shakes, thereby inviting the animals to descend from the trees, after which they are easily caught. According to this Indian, his countrymen do not think that the snake, in any manner, accomplishes the business with its eyes. A Choktah Indian assured the Doctor, that the rattle snake does charm birds, &c.; but he was honest enough to confess, that he did not know in what manner it does it. The interpreter, through whom the conversation was carried on with this Indian, said that the snake charms by means of its rattle.

This opinion of the interpreter was the opinion of Dr Mead. That eminent naturalist, contending, about fifty years ago, the common opinion, that Providence has furnished the rattle-snake with its rattle to give warning to travellers, was the first who asserted that this singular appendage is given to the animal to terrify squirrels and small birds, which are then so stupified by the sight of so formidable an enemy, that at length they drop down, and become its prey; and that this is what the Indians call *fascination*. The same opinion has been adopted by professor Blumenbach of Gottingen, who, in his *Manual of Natural History*, thus expresses himself on this curious subject:

"That squirrels, small birds, &c. fall down spontaneously from trees into the mouth of the rattle-snake, lying

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lying below them, is an undisputed fact; and is the less surprising, as the like phenomena have been remarked in regard to other snakes, and also toads, hawks, and cats; all of which, in certain circumstances, as appears, have the power of drawing towards them small animals, merely by fixing their eyes steadfastly on them. In regard to the rattle-snake, this effect is produced by the rattle in its tail, the hissing noise of which makes squirrels, &c. whether through curiosity, mistake, or terror, seem to approach the animal as it were spontaneously. At any rate, I know, from the information of intelligent eye-witnesses, that it is a common stratagem of the young savages in America to conceal themselves in the bushes, where they imitate the hissing noise of the rattle-snake, and by these means attract squirrels, which they are then enabled to catch."

To this opinion Dr Barton opposes an insuperable objection. It is, that this fascinating power is by no means peculiar to the rattle-snake. With regard to the stratagem of the savages, he thinks that Dr Blumenbach has been imposed upon; as neither he, nor any other person of whom he made the inquiry, ever heard of such a stratagem. The young Indians, he says, place a reed cross-wise in their mouth, and by a tremulous motion of the lips, imitate the cry of young birds; by which means they entice the old ones, so that they can easily shoot them: And this practice may have given rise to the story of their imitating the hissing noise of the rattle-snake.

Some have supposed that serpents, under certain circumstances, emit from their bodies a stupifying vapour; and that it is this vapour which produces the effect called *fascination*: But against this opinion Dr Barton alleges the following arguments: "I know, indeed (says he), that in some of the larger species of serpents, inhabiting South America and other countries, there is evolved in the stomach, during the long and tedious process of digestion in these animals, a vapour or a gas, whose odour is intensely fetid. I have not, however, found that this is the case with the rattle-snake, and other North American serpents, that I have examined. But my own observations on this head have not been very minute. I have made inquiry of some persons (whose prejudices against the serpent tribe are not so powerful as my own), who are not afraid to put the heads and necks of the black snake, and other serpents that are destitute of venomous fangs, into their mouths, and have been informed, that they never perceived any disagreeable smell to proceed from the breath of these animals. I have been present at the opening of a box which contained a number of living serpents; and although the box had been so close as to admit but a very small quantity of fresh air, although the observation was made in a small warm room, I did not perceive any peculiarly disagreeable effluvia to arise from the bodies of these animals. I am, moreover, informed

by a member of this society *, who has, for a considerable time, had a rattle-snake under his immediate care, that he has not observed that any disagreeable vapour proceeds from this reptile. On the other hand, however, it is asserted by some creditable persons of my acquaintance, that a most offensive odour, similar to that of flesh in the last stage of putrefaction, is continually emanating from every part of the rattle-snake, and some other species of serpents. This odour ex-

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tends, under certain circumstances, to a considerable distance from the body of the animal. Mr William Bartram assures me, that he has observed 'horses to be sensible of, and greatly agitated by it, at the distance of forty or fifty yards from the snake. They shewed (he says) their abhorrence by snorting, winnowing, and starting from the road, endeavouring to throw their riders, in order to make their escape.'" This fact, related by a man of rigid veracity, is extremely curious; and, in an especial manner, deserves the attention of those writers who imagine that this fetid emanation from serpents is capable of affecting birds, at small distances, with a kind of asphyxy. It even gives some colour of probability to the story related by Metrodorus, and preserved in the Natural History of Pliny *."

* Lib. 18.

Cap. 14.

Some experiments, however, which were made in Philadelphia a little before the Doctor composed his memoir, seem to have been decisive not only as to the feto, but as to every thing which resembles fascination in the rattle-snake. Birds which were put into a cage which contained a rattle snake, flew or ran from the reptile, as though they were sensible of the danger to which they were exposed. The snake made many attempts to catch the birds, but could seldom succeed. When a dead bird was thrown into the cage, the snake devoured it immediately. He soon caught and devoured a living mole, an animal much more sluggish than the bird. Dr Barton himself saw a snow-bird (see *EMBERIZE, Encycl.*) in a cage with a large rattle snake. The little animal had been thus imprisoned for several hours when he first saw it, but it exhibited no signs of fear. It hopped about from the floor of the cage to its roost, and frequently perched on the snake's back. Its chirp was nowise tremulous, but perfectly natural. It ate the feeds which were put into the cage; and by its whole actions most evidently demonstrated that its situation was not uneasy.

Having thus disposed of the doctrines of some of his predecessors, Dr Barton proceeds to say: "The result of not a little attention to the subject has taught me, that there is but one wonder in the business;-- the wonder that the story should ever have been believed by a man of understanding and of observation." Fascination, we are informed, is almost entirely limited to birds that build low, and "in almost every instance, I found that the supposed fascinating faculty of the serpent was exerted upon the birds at the particular season of their laying their eggs, of their hatching, or of their rearing their young, still tender and defenceless. I now began to suspect that the cries and fears of birds supposed to be fascinated originated in an endeavour to protect their nest or young. My inquiries have convinced me that this is the case."

The rattle-snake, which is the laziest of all the serpent tribe, never moves in a spiral manner or climbs up trees; but the black-snake, and some other species of the genus coluber, do. When impelled by hunger, and incapable of satisfying it by the capture of animals on the ground, they begin to glide up trees or bushes upon which a bird has its nest. The bird is not ignorant of the serpent's object. She leaves her nest, whether it contains eggs or young ones, and endeavours to oppose the reptile's progress. In doing this, she is actuated by the strength of her instinctive attachment to her eggs, or of affection to her young. Her cry is melancholy,

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her motions are tremulous. She exposes herself to the most imminent danger. Sometimes she approaches so near the reptile that he seizes her as his prey. But this is far from being universally the case. Often she compels the serpent to leave the tree, and then returns to her nest.

It is a well known fact, that among some species of birds, the female, at a certain period, is accustomed to compel the young ones to leave the nest; that is, when the young have acquired so much strength that they are no longer entitled to all her care. But they still claim some of her care. Their flights are awkward, and soon broken by fatigue. They fall to the ground, where they are frequently exposed to the attacks of the serpent, which attempts to devour them. In this situation of affairs, the mother will place herself upon a branch of a tree or bush, in the vicinity of the serpent. She will dart upon the serpent, in order to prevent the destruction of her young: but fear, the instinct of self-preservation, will compel her to retire. She leaves the serpent, however, but for a short time, and then returns again. Oftentimes she prevents the destruction of her young, attacking the snake with her wings, her beak, or her claws. Should the reptile succeed in capturing the young, the mother is exposed to less danger; for, whilst engaged in swallowing them, he has neither inclination nor power to seize upon the old one. But the appetite of the serpent tribe is great: the capacity of their stomachs is not less so. The danger of the mother is at hand when the young are devoured. The snake seizes upon her: and this is the catastrophe, which crowns the tale of fascination!

FAUSSE BRAYE, in fortification, an elevation of earth, about three feet above the level ground, round the foot of the rampart on the outside, defended by a parapet about four or five fathoms distant from the upper parapet, which parts it from the berme and the edge of the ditch. The fausse-braye is the same with what is otherwise called *Chemin des rondes*, and *Basse enceinte*; and its use is for the defence of the ditch.

FEATHER-EDGED, is a term used by workmen for such boards as are thicker on one edge, or side, than on the other.

FELTING, the method of working up wool or hair into a kind of cloth or stuff, without either spinning or weaving it. In this country felting it little practised except in hat-making; and as nine-tenths of those who are employed in the manufacturing of hats know nothing of the principles on which they proceed, the following observations on the mechanism of felting must to them be both agreeable and useful. They are by M. Monge, and taken from the *Annales de Chemie*.

If we examine, in a microscope, human hair, wool, the hair of a rabbit, hare, beaver, &c. however great the magnifying power of the instrument may be, the surface of each hair appears perfectly smooth and even; or at least, if any inequalities are to be perceived, they seem rather to arise from some difference in the colour and transparency of particular parts of these substances than from the irregularity of their surfaces; for their image, when viewed by a solar microscope, is terminated by even lines, without any roughness. The surface of these objects, however, is by no means smooth; on the contrary, it appears to be formed either of *lamella* which cover each other from the root to the

point, pretty much in the same manner as the scales of a fish cover the animal from the head to the tail; or, more probably, of zones placed one over the other, like what is observed in the structure of horns: to this conformation it is that the substances here treated of owe their disposition to what is called felting.

If, with one hand, we take hold of a hair by the root, and draw it between two fingers of the other, from the root towards the point, we are hardly sensible of any friction or resistance, nor can we distinguish any sound; but if, on the contrary, we hold the hair at the point, and draw it between the fingers, from the point toward the root, we are sensible of a resistance which did not exist in the former case; a sort of tremulous motion is likewise produced, which is not only perceptible to the touch, but may also be distinguished by the ear.

It is evident, therefore, that the texture of the surface of a hair is not the same from the root towards the point as from the point towards the root; and that a hair, when grasped, must offer more resistance in sliding or moving progressively towards the point than towards the root; *i. e.* in moving with its point foremost.

If a hair, after being taken hold of by the fore-finger and thumb, be rubbed by them, in the longitudinal direction of the hair, a progressive motion takes place, and this motion is always towards the root. This effect does not at all depend on the nature of the skin of the fingers or its texture; for if the hair be turned, so that the point is placed where the root was, the movement then becomes contrary to what it was before; that is to say, it is always directed towards the root.

What is observed, in the above instance, is entirely analogous to what happens when country children, by way of sport, introduce an ear of rye or barley between the wrist and the shirt, the points of the beards of which are directed outwards. By the various motions of the arm, this ear, sometimes catching against the shirt, sometimes against the skin, takes a progressive motion backwards, and soon gets up to the arm-pit. It is very clear that this effect is produced by the beards of the ear, and indeed chiefly by the asperities upon those beards; which, being all directed towards the point, do not permit the ear to move in any other direction than towards that part to which it was united to the stalk. There is no doubt that it is the same with respect to hair; and that its surface is beset with asperities, which, being laid one upon the other, and turned towards the points, permit no motion but towards the root.

A tight knot, made in the middle of a hair, is very difficult to untie by the usual means, on account of the extreme thinness of the hair; but if we place the hair in the bend of the hand, so that the knot is in a line with the little finger, and, after grasping the hair by closing the hand, we strike the fist several times against the knee, the asperities of one end of the hair being now in a contrary direction to those of the other, each of the ends recedes a little, one of them one way, the other the contrary way; the knot is thereby opened, and, by introducing a pin into the eye which is formed, it is very easy to finish untying it.

These observations, which it would be useless to multiply, relate to long hair, that having been taken as an example; but they apply with equal propriety to wool, furs,

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Felting. furs, and in general to every kind of animal hair. The surface of all these is therefore to be considered as composed of hard *lamellæ* placed one upon another, like tiles, from the root to the point; which *lamellæ* allow the progressive motion of the hair towards the root, but prevent a similar motion towards the point.

From what has been said, it is easy to explain why the contact of woollen stuffs is rough to the skin, while that of linen or cotton cloths is smooth; the reason is, the asperities upon the surface of the fibres of the wool (notwithstanding the flexibility of each particular fibre), by fixing themselves in the skin, produce a disagreeable sensation, at least till we are accustomed to it; whereas the surface of the fibres of hemp or flax, of which linen is made, being perfectly smooth, do not cause any such sensation. It is also evident, that the injury arising to wounds or sores, from the application of wool, does not proceed from any chemical property, but is occasioned solely by the conformation of the surface of the fibres: the asperities of which attach themselves to the raw and exposed flesh, which they stimulate and irritate to such a degree as to produce inflammation.

This conformation is the principal cause of that disposition to what is called felting, which the hair of all animals in general possesses.

The hatter, by striking the wool with the string of his bow (see *HAT*, *Encycl.*), separates the hairs from each other, and causes them to spring up in the air; the hairs fall again on the table, in all possible directions, so as to form a layer of a certain thickness, and the workman covers them with a cloth, which he presses with his hands, moving them backwards and forwards in various directions. This pressure brings the hairs against each other, and multiplies their points of contact; the agitation of them gives to each hair a progressive motion toward the root; by means of this motion the hairs are twisted together, and the *lamellæ* of each hair, by fixing themselves to those of other hairs which happen to be directed the contrary way, keep the whole in that compact state which the pressure makes it acquire. In proportion as the mass becomes compact, the pressure of the hands should be increased; not only to make it more close, but also to keep up the progressive motion and twisting of the hairs, which then takes place with greater difficulty: but throughout the whole of this operation, the hairs fix themselves only to each other, and not to the cloth with which they are covered, the fibres of which, as we have already said, are smooth, and have not that disposition to felting which we have described above.

It may not be amiss here to explain why that hair which is intended for making hats is always cut off with a sharp instrument (although that cannot be done without losing a part of its length), and not plucked out by the roots, as might be done after softening the skin: the reason is, the bulb of the hair, which in the latter case would come out with it, would render that end which was fixed in the skin thick and obtuse; and it would consequently be less disposed to introduce itself among the contiguous hairs, and to contribute by its progress motion to the texture of the mass.

The above described conformation of the surface of hairs and wool is not the only cause which produces their disposition to felting. It is not sufficient that every hair possesses the forementioned tendency to move

progressively towards the root, and that the inclined *lamellæ*, by hooking themselves to each other, preserve the mass in that state to which compression has brought it; but it is also necessary that the hairs should not be straight, like needles; if they were so, pressing and rubbing them together would merely cause them to continue their progressive motion, without changing their direction; and the effect of those operations would only be to make them move from the centre of the mass, without producing any compactness in it. Every hair must therefore be twisted or curled in such a manner that the extremity which is towards the root may be disposed to change its direction perpetually, to twist itself about other hairs, and to incline towards itself again, in case it should be determined thereto by any change in the position of the rest of its length. It is because wool has naturally this crooked form that it is so proper for felting, and that it may be made use of for that purpose without undergoing any previous preparation.

But the hairs of the beaver, the rabbit, the hare, &c. being naturally straight, cannot be employed alone in felting till they have undergone a preliminary operation; which consists in rubbing or combing them, before they are taken off the skin, with a brush dipped in a solution of mercury in aquafortis (nitric acid). This liquor, acting only on one side of the substance of the hairs, changes their direction from a right line, and gives them that disposition to felting which wool naturally possesses.

When the hairs are not intended to enter into the body of the mass, but are only to be employed in making a sort of external coating, such as is sometimes given to the outer surface of hats, the operation just mentioned need not be performed; but the felt on which they are to be fixed being finished; the hair is uniformly spread upon the surface to which the coating is to be applied; and, being covered with a cloth, it is pressed with the hands, and agitated for a certain time. By these means, the hairs introduce themselves, by the root, a certain depth into the felt, and are there fixed by their *lamellæ* in such a manner as not to be easily extracted. A particular direction is afterwards given to them by means of a brush, and they are made to keep this direction by having a hot iron passed over them. If the agitation were continued for a longer time, these hairs, not having their straightness destroyed by the operation before described, would pass entirely through the felt, going out at the opposite surface, as each hair follows exactly the direction it acquired at the beginning.

It is owing to the very same circumstances which make wool and hair capable of felting, that woollen cloth is thickened by fulling. See *FULLING* in this Supplement.

FERGUSSON (Robert), who at an early period of life obtained a considerable degree of celebrity as a Scottish poet, was born at Edinburgh on the 5th of September 1750, according to a manuscript account of him with which we have been favoured by a relation. In the biographical sketch prefixed to the Perth edition of his poems he is said to have been born in 1751.

His father William Fergusson possessed, as well as himself, some talents for poetry; but, marrying early, and being wiser than his son, he abandoned the muses

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Fergusson. for trade, and was employed in different mercantile houses, first in Aberdeen and afterwards in Edinburgh. At the time of his death he was an accountant in the British Linen Hall; but never acquired any thing like opulence.

During the years of infancy and childhood the constitution of our poet was so weak, that little hopes were entertained of his arriving at manhood. By the care, however, and attention of his parents, he gradually acquired strength, and at the age of six was put to an English school, where his proficiency in reading and reciting was uncommonly great. At the age of seven he was sent to the high school of Edinburgh, where he continued four years, and with very little labour made a rapid progress in the knowledge of the Latin tongue; but for some reason or other he was removed from the high school to the grammar school of Dundee, whence, after two years, he was sent to the university of St Andrew's. A gentleman of the name of Fergusson had left bursaries in that university for the education of two boys of the same name; and Mr William Fergusson having with difficulty obtained one of them for his son, was induced to educate him at St Andrew's in preference to Edinburgh.

Though at no period of his life a severe student, our poet's attainments in science were such as to keep alive in the university the hopes which had been formed of him at school; and he was confessedly the first mathematician of his standing. On this account we are told that he became the favourite of Dr Wilkie, who was then professor of natural philosophy in the university of St Andrew's; but it is not improbable that the Doctor valued him as much for his poetical genius as for his skill in geometry; for Wilkie was a poet himself, and Mr Fergusson had already written several small poems which attracted considerable notice, as well from the professors as from his fellow-students. But whatever was the bond of union, Dr Wilkie patronised the youthful poet; and the poet shewed afterwards that he was not ungrateful. Upon the Doctor's death, he published, in the Scottish dialect, a beautiful eclogue to his memory, in which the peculiar merits of that eccentric genius are appreciated with great judgment. See WILKIE, in this Supplement.

During the last winter that he resided in St Andrew's, our poet had collected materials for a tragedy on the death of Sir William Wallace, and had even completed two acts of the play; but having seen a similar work on the same subject, he abandoned his design; "because (said he to a friend) whatever I publish shall be original, and this tragedy might be considered as a copy."

Having finished his studies at the university, he returned to Edinburgh without resolving on any permanent employment. His father had designed him for the church; but he was now dead, and our author turned a deaf ear to the intreaties of his mother, and of every other friend who endeavoured to persuade him to fulfil his father's intention. He was then advised to study physic; but he declined it, because, he said, that, when reading the description of diseases, he fancied that he felt the symptoms of them all in himself. To the law, however, he could not start the same objection; and he began to study it, but made no progress. At this his relation and the editor of his poems express no

Fergusson. surprise; for, according to them, it was a study the most improper for him, as it could not be expected that a genius so lively would submit to the drudgery of that dry and sedentary profession.

That the law was a very improper profession for a man of his narrow fortune is indeed true; but we trust that his two biographers will not consider us as intending any offence to them, if we embrace the present opportunity of exposing the folly of a very common remark, that a lively genius cannot submit to what is absurdly called a dry study. We might instance different lawyers at our own bar, who, with great poetical talents in their youth, have risen to the summit of their profession; but to avoid personal distinctions at home, we shall take our examples from England. The genius of the late Earl of Mansfield was at least as lively as that of Mr Fergusson, and if he had pleased he could have been equally a poet; yet he submitted to the drudgery of studying a law still drier than that of Scotland. To the fine taste of Atterbury bishop of Rochester, and to his classical compositions both in prose and verse, no man is a stranger who is at all conversant in English literature; yet that elegant scholar and poet, after he had risen to the dignity of Dean of Carlisle, submitted to the drudgery of studying, through the medium of barbarous Latin, the ecclesiastical law of England from the earliest ages; and declared, that by dint of perseverance he came in time to relish it as much as the study of Homer and Virgil. Whatever be thought of Milton's political principles, no man can read his controversial writings, and entertain a doubt but that he could have submitted to the drudgery of studying the law.

The truth is, and it is a truth of great importance, that a man of real vigour of mind may bring himself to delight in any kind of study which is useful and honourable. Such men were Lord Mansfield, the Bishop of Rochester, and Milton; but, whether through some radical defect in his nervous system, or in consequence of early dissipation, Mr Fergusson, with many estimable qualities, was so utterly destitute of this mental vigour, that rather than submit to what his friends call drudgery, he seems to have looked with a wishful eye to some sinecure place.

With this view he paid a visit to an uncle who lived near Aberdeen, a man of great learning and in opulent circumstances, in hopes that, by his interest, he might be settled in a post suitable to his merit: But how delusive were his hopes! His uncle indeed received him with every mark of affection; but his fondness gradually cooled, and at the end of six months he ordered him abruptly to leave his house, without having endeavoured to procure for him any settlement.

To a mind like Fergusson's, feelingly alive, such treatment from so near a relation, to whom he had always behaved with becoming respect, must have been dreadfully galling. Stung with indignation, he returned to his mother's at Edinburgh; and as soon as he recovered from a severe illness, brought upon him by disappointment and the fatigue of his journey, he composed two elegies; one on "The Decay of Friendship," and the other "Against Repining at Fortune," both occasioned by his adventure in the North. How much he felt the dashing of his hopes, is apparent from the following pathetic lines in the Decay of Friendship:

But,

Ferguſſon.

But, ah! theſe youthful ſportive hours are fled,
 Theſe ſcenes of jocund mirth are now no more;
 No healing ſlumbers 'tend my humble bed,
 No friends condole the ſorrows of the poor.

And what avail the thoughts of former joy?
 What comfort bring they in the adverſe hour?
 Can they the canker-worm of Care deſtroy,
 Or brighten Fortune's diſcontented ſour?

So deſtitute was he at this period, that he ſubmitted to copy papers in the commiſſary clerk's office, we believe at ſo much the ſheet; but not liking the employment, and quarrelling with the commiſſary clerk-depute, he ſoon left the office in diſguſt.

Hitherto he had lived rather in obſcurity; and happy had it been for him if in that obſcurity he had been ſuffered to remain; happy had it been for him, had his converſation been leſs fascinating, and his company leſs courted by the frolic and the gay. Poſſeſſing an inexhaustible fund of wit, the beſt good nature, much modesty, and great goodneſs of heart, he was viewed with affection by all to whom he was known; but his powers of ſong, and almoſt unrivalled talents for mimicry, led him oftener into the company of thoſe who wiſhed for him merely to enliven a ſocial hour, than of ſuch as by their virtue were inclined, and by their influence were able, to procure him a competent ſettlement for life. The conſequence of this was great laxity of manners. His moral principles indeed were never corrupted, nor, as we have reaſon to believe, his faith in revelation ſhaken; but there is no doubt but that, courted as he was by the ſiren voice of pleaſure, he yielded to many temptations, and in the hours of ebriety committed actions which, in his cooler moments, he reflected on with abhorrence.

His conſcience was indeed frequently roused. Being on a viſit to a friend at Haddington, and ſauntering one day near the churchyard, he was accoſted by a clergyman, who ſeemed to be no ſtranger to the kind of life which he led. This judicious divine contrived to draw his attention to the ſhortneſs of time, the length of eternity, death and judgment, and the awful ſtate that awaits the wicked in an unſeen world; and the converſation made a deep impreſſion on his mind. It ſeemed, however, to be effaced from his memory by the diſſipation of Edinburgh, till it was recalled with double effect by the following accident:

In the room adjoining to that in which he ſlept was a ſtarling, which being ſeized one night by a cat that had found its way down the chimney, awaked Mr Ferguſſon by the moſt alarming ſcreams. Having learned the cauſe of the alarm, he began ſeriouſly to reflect how often he, an immortal and accountable being, had in the hour of intemperance ſet death at defiance, though it was thus terrible in reality even to an unaccountable and ſinleſs creature. This brought to his recollection the converſation of the clergyman, which, aided by the ſolemnity of midnight, wrought his mind up to a pitch of remorſe that almoſt bordered on frantic deſpair. Sleep now forſook his eyelids; and he roſe in the morning, not as he had formerly done, to mix again with the ſocial and the gay, but to be a recluſe from ſociety, and to allow the remembrance of his paſt follies to prey upon his vitals. All his vivacity now forſook him; thoſe lips which were formed to give delight, were clo-

ſed as by the hand of death; and "on his countenance ſat horror plum'd."

From this ſtate of gloomy deſpondency, however, he began gradually to recover; and, except that a ſettled melancholy was viſible in his countenance, his health was completely reſtored, when one evening he fell and cut his head ſo dreadfully, that from the loſs of blood he became delirious. In this deplorable ſtate he continued for ſeveral months, till, being quite exhausted by want of ſleep and conſtant ſpeaking, he expired on the 16th of October 1774. He was interred in the Canon-gate churchyard, where his friends erected a monument to his memory, which has been ſince removed to make way for a larger and more elegant monument by his enthuſiaſtic admirer the late poet BURNS.

Thus died Robert Ferguſſon, a young man of the brighteſt genius and of the beſt heart, who, had he joined prudence to his uncommon talents, muſt have riſen to great eminence in the republic of letters; but, as a late juvenile poet has obſerved of him—

Complete alike in head and heart,
 But wanting in the prudent part,
 He prov'd a poet's lot.

Of his poems no general character can be given. The ſubjects of them are ſometimes uncommon and generally local or temporary. They are of courſe very unequal. But ſuch of them as are in the Scotch dialect have been univerſally admired by his countrymen; and when it is conſidered that they were compoſed amidſt a round of diſſipation, they will be allowed to furniſh complete evidence of his genius and his taſte.

FERMAT (Peter), who was counſellor of the parliament of Toulouſe in France, flouriſhed in the 17th century, and died in 1663. He was a man of great talents, and a very general ſcholar; but being contemporary and intimately connected with Des Cartes, Merſenne, Torricelli, and Huygens, he was naturally led to devote much of his time to the mathematical ſciences. He was (ſays Dr Hutton) a firſt rate mathematician, and poſſeſſed the ſineſt taſte for pure and genuine geometry, which he contributed greatly to improve, as well as algebra.

Fermat was author of, 1. A Method for the Quadrature of all ſorts of Parabolas.—2. Another on Maximums and Minimums: which ſerves not only for the determination of plane and ſolid problems, but alſo for drawing tangents to curve-lines, finding the centres of gravity in ſolids, and the reſolution of queſtions concerning numbers: in ſhort, a method very ſimilar to the fluxions of Newton.—3. An Introduction to Geometric Loci, plane and ſolid.—4. A Treatiſe on Spherical Tangencies: where he demonſtrates in the ſolids the ſame things as Vieta demonſtrated in planes.—5. A Reſtoration of Apollonius's two Books on Plane Loci.—6. A General Method for the dimension of Curve Lines. Beſides a number of other ſmaller pieces, and many letters to learned men; ſeveral of which are to be found in his *Opera Varia Mathematica*, printed at Toulouſe, in folio, 1675.

FERMENTATION is a chemical proceſs which has been already conſidered in the *Encyclopaedia*, and will be again reſumed in this *Supplement* under the title *Animal and Vegetable SUBSTANCES*. In this place we mean nothing more than to give ſuch directions, principally

Ferguſſon

Ferguſſon
||
Fermentation.

Fermenta-
tion.

cipally from Mr Richardson of Hull, for the proper fermentation of malt liquors as have not been fully detailed in the article BREWING (*Encycl.*).

This author controverts, we do not think very successfully, the conclusions drawn by Mr Henry from the experiments, of which the reader will find an account in the article FERMENTATION (*Encycl.*); but it is not his theory with which we are at present concerned, but his practice as that of an experienced and enlightened brewer. Having treated of *Worts*, and the proper method of boiling them, for which see *WORT* in this *Supplement*, and having given an historical view of the process of fermentation, of which a pretty accurate abridgement is inserted in the articles BREWING and FERMENTATION (*Encycl.*), he proceeds thus:

“The agency of air, in the business of fermentation, is very powerful; but as all fermentable subjects have an abundant supply, we are rather to provide for the egress of their own, than to suffer the admission of the external air, by which a great number of the fine, volatile, oleaginous parts of the subject would be carried off, and a proportionate injury in flavour and spirituousity sustained. Hence such a covering should be provided for the gyle-tun as would barely allow the escape of the common air produced by the operation; whilst the *gas*, or fixed air, from its greater density, resting upon the surface of the beer the whole depth of the curb, prevents the action of the external air, and consequently the escape of those fine and valuable parts just mentioned.

“But towards the conclusion of vinous fermentation, this aerial covering begins to lose its efficacy; which points out the necessity of then getting the beer into casks as soon as possible, that the consequences may be prevented, of exposing so large a surface, liable to so copious an evaporation. Amongst these, a loss of spirituousity is not the least; for this evaporation is more and more spirituous, as the action approaches the completion of vinous fermentation; and that once obtained, the loss becomes still more considerable, if still exposed to the air; whence it might be termed the distillation of Nature, in which she is so much superior to art, that the ethereal spirit rises pure and unmixed, whilst the highest rectification of the still produces at best but a compound of aqueous and spirituous parts.

“Nor is this entirely conjecture. Experience teaches us, that we cannot produce so strong a beer in summer, *ceteris paribus*, as in winter; the reason is, not because the action of fermentation does not realize so much spirit in warm weather, but because the fermenting liquor, after the perfection of vinosity, continues so long in a state of rarefaction, that the spirituous parts are dissipated in a much greater degree at that time than at any other, in a similar state of progression. And this doctrine of natural distillation seems to account for that increase of strength obtainable from long preservation, in well closed casks, and, more particularly so, in glass bottles; for Nature, in her efforts to bring about her grand purpose of resolving every compound into its first principles, keeps up a perpetual internal struggle, as well as an external evaporation; and if the latter be effectually prevented, the former must be productive of additional spirituousity, so long as the action keeps within the pale of vinous fermentation.

Fezzan.

“In order to maintain a due regulation of the fermenting power, and to answer the several purposes of the operation, a scrupulous attention to the degree of heat at which the action commences, and a particular regard to the quality and quantity of the ferment employed, are indispensably necessary.” The degree of heat must be ascertained by the thermometer, and regulated by experience: the quantity of yeast can be ascertained only by the intention of the artist.

FEZZAN is a kingdom in the anterior of Africa, placed in the vast wilderness as an island in the ocean. The following account of it was given to Mr Lucas the African traveller by an old sheeref, a native of Fezzan; and that account was confirmed by the governor of Mesurata, who had himself visited Fezzan, and who, having treated the traveller with great kindness, ought not to be suspected of having wantonly deceived him.

According to this account, Fezzan is situated to the south of Mesurata (see *MESURATA* in this *Suppl.*), and the traveller from the latter place to the former arrives in eight days at Wadan, where refreshments are procured for the caravan. From thence in five hours they reach the desert of Soudah, where no vegetable is seen to grow but the talk, a tree from which the lemon-coloured wood is taken which forms handles for tools. The passage of the desert takes up some days, when the traveller finds a miserable village, producing nothing but dates, brackish water, and Indian corn; from this village a day's journey conducts to the town of Sebbah, where are the remains of an ancient castle, and other venerable ruins, and in four days more he reaches Mourzouk, the capital of Fezzan.

This city is situated on the banks of a small river, surrounded by a high wall for defence, and is distant from Mesurata 390 computed miles. Eastward of Mourzouk is the town of Queela, in which are the remains of ancient buildings; the size of the cisterns, and the construction of the vaulted caves, exhibit instances of ancient splendour. South of which place is Jermah, distinguished by numerous and majestic ruins, on which are many inscriptions. Tessouwa lies eastward, near which was a river which the sheeref remembers, but is now overwhelmed in the moving sands. N. E. from Mourzouk, distant about 120 miles, is the large town of Temmiswa, where the caravans of pilgrims from Bornou and Nigritia, by way of Cairo to Mecca, provide their stores for the desert.

In the town or province of Mendrah is a large quantity of *irona*, a species of fossil alkali, that floats on the surface or settles on the banks of its spreading lakes, great quantity of which is sent to Tripoli, and shipped for Turkey, Tunis, and Morocco; at the latter place it is used as an ingredient in the red dye of the leather. Mendrah is about 60 miles south of Fezzan. The territory of Fezzan extends but little westward, being confined by barren mountains. The smaller towns of this kingdom are said to be about one hundred; these towns are chiefly inhabited by husbandmen and shepherds; in every town a market is regularly held; mutton and goat's flesh are sold by the quarter, usually from thirty-two to forty grains of gold, or from four to five shillings English. The flesh of camels is dearer, and divided into smaller parts.

The houses are of clay, with flat roofs composed of branches

Fezzan.

branches of trees, on which earth is laid; this is sufficient in a climate where it never rains. The heats in summer, from April to November, are intense, and the hot winds blow from the south-east, south, and south-west, with such violence as to threaten suffocation; when it changes to the west or north-west a reviving freshness ensues.

The dress of the inhabitants is like that of the Moors of Barbary, consisting of a large pair of trowsers, a shirt which hangs over the trowsers, a kind of waistcoat without sleeves, and a jacket with tight sleeves; over the jacket is a loose robe which reaches below the knee, a girdle of crimson, and a long cloth called a *barrakon* or *albaikue*, like a highland plaid, is worn; stockings of leather, laced like half-boots, and slippers; on the head a red cap and turban; sometimes over the whole they throw a long cloak with a hood, called a *burnoose*. In summer they throw off all but the shirt and the cap.

The people bear very high degrees of heat, but any cold affects them sensibly. Their diseases are chiefly of the inflammatory and putrid kind; the small pox is common. Their old women are their principal physicians. For pains in the head they cup and bleed; for those in the limbs, they bathe in the hot lakes. They have a multitude of noxious and loathsome animals; the air is crowded with mosquitos, and their persons are over-run with the vermin which affect the beggars of Europe.

In their persons they incline to the negro, of a deep swarthy complexion, with curly black hair; they are tall, but indolent, inactive, and weak. In their common intercourse, distinction of rank seems to be forgotten; rich and poor, master and man, converse, eat, and drink together; they are, however, generous and hospitable.

An extensive plain composes the kingdom of Fezzan: the soil is generally a light sand, the springs are abundant, and few regions in Africa exhibit a richer vegetation. The land produces the talk, the white thorn, date trees, the olive and lime, apricot, pomegranate, and fig: Indian corn and barley are the favourite objects of cultivation; of wheat there is little raised. The tame animals are, the sheep, cow, goat, and camel; and the wild are, the ostrich, antelopes of various kinds, one of which is called the *luadee*, which when chased plunges with address from a precipice, and lights on its hams.

The food of the lower class consists of flour of Indian corn, seasoned with oil and fruit; those of superior rank eat wheat bread and flesh. Fezzan produces much salt; the water has in general a mineral taste, but the favourite beverage is a liquor from the date tree, which acquires, when fermented, an intoxicating strength. In religion they are rigid Mahomedans, but tolerant. Their government monarchical; their present king is descended from one of the shereefs of Tassilet, who about 400 years since obtained the crown. Till the present century the kingdom was independent, when the Bahaw of Tripoli conquered and made it tributary; the reigning sovereign has nearly thrown off this yoke. In Fezzan, the descendants of the prophet are highly privileged, their property and persons are inviolable; they are exempt from certain punishments. This class are in general either princes or merchants.

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Fezzan.

The revenue is composed of a tax on towns and villages, a tax on every camel load of goods (except provisions) which enters the capital, fines for offences, lands of persons dying without heirs, and a tax on gardens and date trees. Gold dust by weight is the chief medium of payment; but for convenience they are furnished with small papers of gold dust of different values, from two *xarbes* or one and a half upwards; for smaller articles corn or flour are used as a medium. One grain of gold is equal to $1\frac{1}{2}$ d. sterling. The Fezzan grain is the same as in England.

The justice of the sovereign is highly extolled; small offences are punished by the bastinado, and the punishments increase to fine, imprisonment, and death. Trusting to their natural defence, their towns are without guard, and they have no standing forces. The only war the shereef remembered was undertaken against a people inhabiting the mountains of Tibesti, which is separated from the people of Fezzan by a wide and sandy desert. These people are wild and savage, and had plundered a caravan belonging to the king, who sent an army of between 3 and 4000 men against and subdued them. The country of these people produces much fenna. The vales of Tibesti are said to be fertile in corn and pasture for cattle, particularly camels. The people live in huts, and profess various religions, some the Mahomedan, others are attached to their ancient idolatry.

The people of Fezzan carry on a considerable trade with Tripoli, Bornou, Nigritia, &c. At the end of October, when the heats are abated, the caravans depart from Mourzouk in small parties of ten or twelve, unless in time of war. They lay in provisions of dates, meal, and mutton salted, dried in the sun, and boiled in oil or fat. The merchants have agents in the chief towns, to whom they send the slaves they purchase.

The caravans to Tripoli carry the *trona*, fenna, gold and slaves brought from the southern countries; and in return bring back cutlery, woollen, silks, dollars, copper, and brass.

That to Bornou carries brass and copper, for the currency of the country, imperial dollars, and various manufactures; but of their own produce only a preparation of dates, and meal of Indian corn; and they take in return slaves, gold dust, and civet.

To Cashna, an empire in Nigritia, they carry cowries, brass to make rings and bracelets, horses, several kinds of manufactures, and the Gooroo nuts; and in return take gold dust, slaves, cotton cloth, dyed goats skins, hides, fenna, and civet, for the countries south of the Niger, where also they convey sabre blades and Dutch knives, coral, brass beads, looking glasses, dollars, &c. and receive back gold dust, slaves, cotton cloths, goat skins, Gooroo nuts, cowries, and ivory.

A caravan of pilgrims sets out likewise in the autumn of every second or third year from Mourzouk, the capital of Fezzan, to Mecca. They proceed to Temessa, over the mountain of Ziltan, and thence to Sibbul, a place subject to Tripoli; and thence nearly in a line with the Mediterranean sea to Cairo, and thence to Mecca by the customary route.

As not one celestial observation has been taken to determine any latitude between Benin and Tripoli, all the positions are fixed by estimation, reckoning fifteen or sixteen miles for a day's journey. Mr Rennell places

Figurate. Mourzouk, the capital of Fezzan, in lat. 27°. 20', or 260 miles from Masurata.

FIGURATE NUMBERS are such as do or may represent some geometrical figure, such as a triangle, pentagon, or pyramid, &c. These numbers are treated of at great length by Maclaurin in his Fluxions; Simson in his Algebra; and Malcolm in his Arithmetic; but the following account of them by Dr Hutton is as perspicuous as any that we have seen:

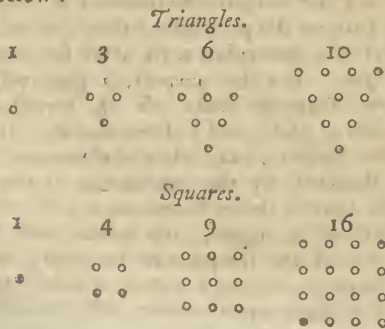
Figurate numbers are distinguished into orders, according to their place in the scale of their generation, being all produced one from another, viz. by adding continually the terms of any one, the successive sums are the terms of the next order, beginning from the first order, which is that of equal units 1, 1, 1, 1, &c.; then the second order consists of the successive sums of those of the first order, forming the arithmetical progression 1, 2, 3, 4, &c.; those of the third order are the successive sums of those of the second, and are the triangular numbers 1, 3, 6, 10, 15, &c.; those of the fourth order are the successive sums of those of the third, and are the pyramidal numbers 1, 4, 10, 20, 35, &c.; and so on, as below:

Order.	Name.	Numbers.
1.	Equals,	1, 1, 1, 1, 1, &c.
2.	Arithmeticals,	1, 2, 3, 4, 5, &c.
3.	Triangulars,	1, 3, 6, 10, 15, &c.
4.	Pyramidals,	1, 4, 10, 20, 35, &c.
5.	2d Pyramidals,	1, 5, 15, 35, 70, &c.
6.	3d Pyramidals,	1, 6, 21, 56, 126, &c.
7.	4th Pyramidals,	1, 7, 28, 84, 210, &c.

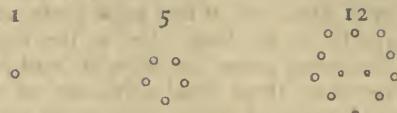
The above are all considered as different sorts of triangular numbers, being formed from an arithmetical progression whose common difference is 1. But if that common difference be 2, the successive sums will be the series of square numbers: if it be 3, the series will be pentagonal numbers, or pentagons; if it be 4, the series will be hexagonal numbers, or hexagons; and so on. Thus:

Arithmeticals.	1st Sums, or Polygons.	2d Sums, or 2d Polygons.
1, 2, 3, 4	Tri. 1, 3, 6, 10	1, 4, 10, 20
1, 3, 5, 7	Sqrs. 1, 4, 9, 16	1, 5, 14, 30
1, 4, 7, 10	Pent. 1, 5, 12, 22	1, 6, 18, 40
1, 5, 9, 13	Hex. 1, 6, 15, 28	1, 7, 22, 50
&c.		

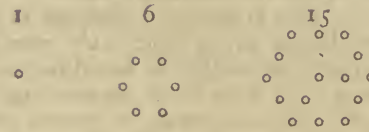
And the reason of the names triangles, squares, pentagons, hexagons, &c. is, that those numbers may be placed in the form of these regular figures or polygons, as here below:



Pentagons.



Hexagons.



Figurate, Filter.

But the figurate numbers of any order may also be found without computing those of the preceding orders; which is done by taking the successive products of as many of the terms of the arithmeticals 1, 2, 3, 4, 5, &c. in their natural order, as there are units in the number which denominates the order of figurates required, and dividing those products always by the first product. Thus the triangular numbers are found by dividing the products 1 × 2, 2 × 3, 3 × 4, 4 × 5, &c. each by the first product 1 × 2; the first pyramids by dividing the products 1 × 2 × 3, 2 × 3 × 4, 3 × 4 × 5, &c. by the first 1 × 2 × 3. And, in general, the figurate numbers of any order *n*, are found by substituting successively 1, 2, 3, 4, 5, &c. instead of *x* in this general expression $\frac{x \cdot x + 1 \cdot x + 2 \cdot x + 3 \cdot x + \dots}{1 \cdot 2 \cdot 3 \cdot 4 \cdot \dots}$; where the factors in the numerator and denominator are supposed to be multiplied together, and to be continued till the number in each be less by 1 than that which expresses the order of the figurates required.

FILTER (See *Encycl.*) It is well known that vessels made of a particular kind of porous stone are employed as filtering basins for freeing water, intended to be drunk, from various kinds of impurity. In sea voyages such filtering basins must be highly useful; and they are frequently found useful at land where no water can be had but from stagnant pools, or springs flowing through clay. The stone, however, of which they are made is not every where to be found; and therefore different persons have endeavoured to employ the art of the potter to supply their place.

In the year 1790 a patent was granted to a female potter, for her invention of the following composition for this purpose; viz. four equal parts, out of nine equal parts, of tobacco-pipe clay; and five equal parts, out of nine equal parts, of coarse sea, river, drift, or pit sand; these two materials, in the above proportions, are sufficient for the purpose of making small basins, and other vessels, to contain a quantity not exceeding one gallon of water, or other liquid. But the composition, when confined to these two materials, and in these proportions, often flies or cracks in the fire, if larger basins, or other vessels, are attempted to be made with it. She, therefore, in the second instance, composes her filtering basins of equal parts of tobacco-pipe clay and coarse sea, river, drift, or pit sand; in the third instance, of three equal parts, out of nine equal parts, of tobacco-pipe clay; one equal part, out of nine equal parts, of Stourbridge clay, or clay from the surface of coal mines, or any other clay of the same quality; one equal part, out of nine equal parts, of Windfor,

Filter.

or other loam, of the same quality with Windsor loam; and four equal parts, out of nine equal parts, of coarse river, sea, drift, or pit sand. Or, in the fourth instance, of four equal parts, out of eight equal parts, of tobacco-pipe clay; three equal parts, out of eight equal parts, of coarse sea, river, drift, or pit sand; and one equal part, out of eight equal parts, of that burnt ground clay of which crucibles are made.

If the lady who invented, or pretends to have invented, these basins, have a right to her patent, far be it from us to wish our readers of any description to in-croach upon it; but as the use of the materials of which her basins are made was known to potters before she was born, they may certainly compound these materials in proportions different from hers, without doing her any legal injury. As she varies her own proportions so much, we think it probable that some proportion differing a little from them all, may answer the purpose of filtering vessels equally well; and it is almost needless to add, that with this precaution any potter may make such vessels, for which he would undoubtedly have a great demand.

A patent has likewise been granted to Mr Joshua Collier of Southwark for a very ingenious contrivance for filtering and sweetening water, oil, and all other liquids. Of this contrivance, which combines the application of machinery with the antiseptic properties of charcoal (See CHEMISTRY n^o 34. Supplement), we shall give a detailed account.

Fish-oil is one of the liquids which he had it particularly in view to free from all its impurities in smell, taste, and colour; and the chemical process employed by him for this purpose, consists in pouring a quantity of any species of fish-oil, or a mixture of different sorts of fish-oil, into any convenient vessel, which is to be heated to the temperature of 110 or 120 degrees of Fahrenheit's scale, and then adding of caustic mineral alkali, of the specific gravity commonly described as 1.25, or of such strength that a phial containing 1000 grains of distilled water will contain 1250 grains of these lees, a quantity equal to four parts of the 100 by weight of the quantity of oil; the mixture is then to be agitated, and left to stand a sufficient time for the salts and sediments to subside; it is then drawn off into another vessel, containing a sufficient quantity of fresh burnt charcoal, finely powdered, or any other substance possessing antiseptic properties, in a powdered or divided state, with an addition of a small proportion of diluted sulphuric acid, sufficient only to decompose the small quantity of saponaceous matter still suspended in the oil, which appears by the oil becoming clear at the surface: the contents of this vessel are also agitated, and the coaly saline and aqueous particles left to subside; after which the oil is passed through proper strainers, herein after described, and is thereby rendered perfectly transparent and fit for use.

The principle of the improved strainers, or filtering machines, consists in the means applied to combine hydrostatic pressure, which increases according to the perpendicular height of the fluid, with the mode of filtering *per ascensum*, thereby procuring the new and peculiar advantage that the fluid and its sediment take opposite directions. A great advantage attending this invention is, that the dimensions of the chamber in which the sediment is received, may be varied, while the

filtering surface remains the same. To adapt the machines not only to the purpose of families, work-houses, hospitals, public charities, the navy, or the merchant service, but also to all the purposes of oil-men, of distillers, of the laboratory, the brewery, &c. chambers of various capacities must be provided for the sediment and precipitated matter. With respect to the oil-trade, the space required is very great, especially for spermaceti, or Brasil bottoms. In the various purposes of the laboratory, no limits can be fixed, but all dimensions will be occasionally required: in distilleries and breweries they may be smaller in proportion; and in that designed for water and for domestic use, a very small chamber will be sufficient. When water is to be sweetened, or freed from any putrid or noxious particles, it passes, in its way to the filtering chamber, through an iron-box, or cylinder, containing charcoal finely powdered, or any other antiseptic substance insoluble in water, the water being forced into it by hydrostatic pressure, through a tube of any sufficient height. This box has two apertures to receive and deliver the fluid, and these are opened and closed by cocks, or screws, or any other method used for such purposes; and being affixed to the machine by other screws, may be easily detached from the same. Thus, whenever the charcoal begins to lose its antiseptic properties, the box is removed and heated till it is red hot; by which means the foreign matter escapes through the small apertures; after which the box is cooled, and the charcoal becomes sweet, pure, and equally fit for use as at first, though the process be ever so often repeated.

Another part of the invention consists in filtering machines in the form of stills, in which charcoal may be repeatedly burned after any fluid substances have passed through it, for the purpose of freeing them either from putrid or noxious particles, or of discharging their colouring matter; which filtering stills are so contrived, that the fluid may pass through in any quantity, without displacing the charcoal: the part of the fluid remaining interspersed among the charcoal, may be driven over by heat, and be employed for many inferior purposes of the arts or manufactures. Lastly, the heat may be raised so as to purify the charcoal, as has been before described in the machines for water. The flue of those stills is so constructed that water may be employed to cool them without the loss of time requisite for their gradually parting with their heat to the surrounding atmosphere, so as to be fit for a subsequent operation.

But it was not merely to the purifying of oils and various liquids that Mr Collier turned his attention. To his filtering apparatus are attached instruments for ascertaining the comparative qualities of oils, which depend in part on the principle of their specific gravities; spermaceti oil, contrasted with other fish oils, being as 875 to 920. For this purpose, a glass vessel of any convenient shape is made use of, furnished with a bubble also of glass, and a thermometer. If the oil is pure, this bubble sinks, when the mercury rises to a certain standard, by the application of the hand, or any other heat to the vessel containing the oil. If the spermaceti oil is impure, the bubble will still float, though it is of the temperature required; and the degree of impure, or foreign matter, will be shown by the state of the thermometer at which the bubble sinks.

Filter.

Filter.

To determine what tendency oils used for burning have to congeal in cold weather, a freezing mixture is put in a phial of thin glass, or any other convenient vessel; into this a thermometer is immersed, and a single drop of the oil, under experiment, suffered to fall on the outside of the vessel, where it immediately congeals: as the cold produced by the mixture gradually ceases, it is easy to observe by the thermometer at what point of temperature the oil becomes fluid, and runs down the side of the glass.

Plate
XXIII.

A short description of this apparatus will make its principles plain to every reader. A (fig. 1.) is the cistern into which the water or other liquor to be filtered is put. B B is a tube opening into the bottom of the cistern A, and bent along the bottom of the machine conveying the fluid into CCC the filtering chamber, which is covered with leather bound down round its circular rim, and through which leather the water is percolated. DD, The basin rising above the level of the chamber and receiving the filtered liquor. E, The spout by which it runs off into a pitcher or other vessel. F, Another spout furnished with a cock to draw off the foul water from the chamber when necessary. GGG, The air tube, which begins above the level of the chamber, is covered with a button, which saves the leather from being cut, and has a small lateral aperture for the air to be carried off. This pipe passes along the bottom and up the side, and rising above the level of the water in the cistern, is there closed, except a small lateral aperture through which the air escapes. H, A guard or rim with cross bars put over the leather to keep it from being forced up by the water. It is fastened down by means of two notches on opposite sides of the guard, by which it locks into two staples rivetted into the bottom of the basin. I, The lid sliding down to cover the water from dust, and suspended at pleasure by means of KK, two springs on each tube for that purpose. LMNO, A cylindrical box containing charcoal, which is connected with the above by means of the tube P, and a continuation of the tube B. LM, The water tube B continued below the charcoal apparatus, so that the fluid may pass through the same into the cylinder, from whence it enters the chambers at P, so as to be filtered through the leather as before described. RR, Collars which may be unscrewed at pleasure, so as to detach the charcoal apparatus whenever the charcoal requires to be purified by heat. SS, Two cocks to direct the fluid through the charcoal cylinder, or immediately into the filtering chamber.

Fig. 2. A, A tub or cistern containing the oil to be filtered, and supplying a tube of sufficient height for the hydrostatic pressure to operate. BB, A main tube of wood, tin, leather, or cloth, to which any number of bags, of the size and shape of corn sacks, or any CC, convenient size or shape may be connected. These are bound to DDD, straight double iron bars, furnished with a hinge at one end and a screw at the other, by opening which the bags may be emptied. F, A trough underneath, made to receive the filtered oil from the receivers EEE.

Fig. 3. A, A funnel cask or cistern, into which the fluid is put which passes down. B, A tube fitted into the same, through which it enters. C, An iron still, or still of any other substance capable of sustaining heat, full of finely powdered and sifted charcoal, through

the head of which the fluid passes into any receiver. D, A fire-place of any construction to drive over the fluid remaining interspersed among the charcoal, and also to purify the charcoal by an increase of temperature when required. E, A cock to let water into the flues to cool the apparatus for a subsequent operation.

Fire.

Fig. 4. The trial glass with its thermometer.

FIRE. See that article *Encycl.* and CALORIC and COMBUSTION, *CHEMISTRY-Index* in this *Suppl.*

Extinction of FIRE is sometimes a matter of so much consequence, that every thing which promises to be effectual for that purpose is worthy of attention. In the nineteenth number of Mr Nicholson's *Journal of Philosophy, Chemistry, and the Arts*, we have the following composition for extinguishing fire, invented by M. Von Aken.

Burnt alum	-	-	-	-	pounds	30
Green vitriol powdered	-	-	-	-		40
Cinabrese or red ochre in powder	-	-	-	-		20
Potter's clay, or other clay, also powdered	-	-	-	-		200
Water	-	-	-	-		630

With 40 measures of this mixture an artificial fire was extinguished under the direction of the inventor by three persons, which would have required the labour of 20 men and 1500 measures of common water. Sig. Fabbroni was commissioned to examine the value of this invention, and found in his comparative trials with engines of equal power, worked by the same number of men, that the mixture extinguished the materials in combustion in one sixth part less time, and three eighths less of fluid than when common water was used. He observed, as might indeed have been imagined from the nature of the material, that the flame disappeared wherever the mixture fell, and that the saline, metallic, and earthy matters, formed an impenetrable lute round the hot combustible matter, which prevented the access of the air, and consequently the renewal of the destructive process.

This recipe, Mr Nicholson informs us, is taken from N° 85. of *Giornale Letterario di Napoli*, in which it was inserted in the form of a letter from Sig. Fabbroni to Sig. D. Luigi Targioni of Naples; and the author of the letter estimates the price of the composition at about one halfpenny per pound.

The reason assigned by Mr Nicholson for giving this abridged account a place in his valuable work, will be admitted by him and the public as a sufficient reason for our adopting it into our's. It is, that such inventions are worthy of the attention of philosophers and economists, even though in the first applications they may prove less advantageous than their inventors may be disposed to think. It is scarcely probable that this practice in the large way, with an engine throwing upwards of 200 gallons (value about L.3, 10s.) each minute, would be thought of or adopted, or that a sufficient store of the materials would be kept in readiness; since at this rate the expenditure for an hour would demand a provision to the amount of L. 210 sterling. But in country places the process, or some variation of it, might be applied with sufficient profit in the result; more especially if it be considered that common salt or alum, or such saline matter as can be had and mixed with the water, together with clay, chalk, or lime, ochreous earth or common mud, or even these last without any salt, may answer the purpose of the

the

Fire. the lute with more or less effect, and extinguish an accidental fire with much greater speed and certainty than clear water would do.

FIRE-Balls are meteors, of which some account has been given in the *Encyclopædia*, as well as of various hypotheses which have been framed respecting their nature and their origin. Since that article was published, a new and very singular hypothesis has been framed by Professor Chladni of Wittenberg, who maintains it by arguments, which, however fanciful, are yet worthy of

**Phil. Mag.* the reader's notice*.

Nos 5 and 7. He supposes that fire-balls, instead of being collections of the electrical fluid floating in the highest regions of our atmosphere, are masses of very dense matter formed in far distant parts of space, and subjected to similar laws with the planets and comets. He endeavours to prove that their component parts must be dense and heavy; because their course shews, in so apparent a manner, the effects of gravity; and because their mass, though it distends to a monstrous size, retains sufficient consistency and weight to continue an exceedingly rapid movement through a very large space, without being decomposed or dissolved, notwithstanding the resistance of the atmosphere. It seems to him probable, that this substance is by the effect of fire reduced to a tough fluid condition; because its form appears sometimes round and sometimes elongated, and as its extending till it bursts, as well as the bursting itself, allows us to suppose a previous capability of extension by elastic fluidity. At any rate, it appears to be certain, that such dense matter at so great a height is not collected from particles to be found in our atmosphere, or can be thrown together into large masses by any power with which we are acquainted; that no power with which we are acquainted is able to give to such bodies so rapid a projectile force in a direction almost parallel to the horizon; that the matter does not rise upwards from the earth, but exists previously in the celestial regions, and must have been conveyed thence to our earth. In the opinion of Dr Chladni, the following is the only theory of this phenomenon that agrees with all the accounts hitherto given, which is not contrary to nature in any other respect, and which besides seems to be confirmed by various masses found on the spot where fire-balls fell.

As earthy, metallic, and other particles form the principal component parts of our planets, among which iron is the prevailing part, other planetary bodies may therefore consist of similar, or perhaps the same component parts, though combined and modified in a very different manner. There may also be dense matters accumulated in smaller masses, without being in immediate connection with the larger planetary bodies dispersed throughout infinite space; and which, being impelled either by some projecting power or attraction, continue to move until they approach the earth or some other body, when, being overcome by its attractive force, they immediately fall down. By their exceedingly great velocity, still increased by the attraction of the earth and the violent friction in the atmosphere, a strong electricity and heat must necessarily be excited; by which means they are reduced to a flaming and melted condition, and great quantities of vapour and different kinds of gases are thus disengaged, which distend the liquid mass to a monstrous size, till, by a still farther ex-

panion of these elastic fluids, it must at length burst. Dr Chladni thinks also, that the greater part of the *shooting stars*, as they are called, are nothing else than fire-balls; which differ only from the latter in this, that their peculiarly great velocity carries them past the earth at a greater distance, so that they are not so strongly attracted by it as to fall down; and therefore, in their passage through the high regions of the atmosphere, occasion only a transient electric flash, or actually take fire for a moment, and are again speedily extinguished, when they get to such a distance from the earth that the air becomes too much rarefied for the existence of fire.

The grounds on which Dr Chladni supports this opinion are various relations, well authenticated, of the motions of those meteors, and the phenomena which accompany their bursting. Besides those mentioned in the *Encyclopædia*, he lays a particular stress on the account which he received from *M. Baudin*, Professor of philosophy at Pau, of a remarkable fiery meteor seen in Gascony on the 24th of July 1790. On the evening of that day M. Baudin was in the court of the castle of Marmes with a friend, the atmosphere being perfectly clear, when they suddenly found themselves surrounded by a whitish light, which obscured that of the full moon, then shining with great lustre. On looking upwards, they observed, almost in their zenith, a fire-ball of a larger diameter than the moon, and with a tail equal in length to five or six times the diameter of the body. The ball and the tail were of a pale white colour, except the point of the latter, which was almost as red as blood. The direction of this meteor was from south to north.

"Scarcely (says M. Baudin) had we looked at it for two seconds when it divided itself into several portions of considerable size, which we saw fall in different directions, and almost with the same appearance as the bursting of a bomb. All these different fragments became extinguished in the air; and some of them, in falling, assumed that blood-red colour which I had observed in the point of the tail. It is not improbable that all the rest may have assumed the same colour; but I remarked only those which proceeded in a direction towards Mormes, and which were particularly exposed to my view.

"About two minutes and a half, or three minutes after, we heard a dreadful clap of thunder, or rather explosion, as if several large pieces of ordnance had been fired off together. The concussion of the atmosphere by this shock was so great, that we all thought an earthquake had taken place. The windows shook in their frames, and some of them, which probably were laid to and not closely shut, were thrown open. We were informed next day, that in some of the houses at Houga, a small town about half a mile distant from Mormes, the kitchen utensils were thrown from the shelves; so that the people concluded there had been an earthquake. But as no movement was observed in the ground below our feet, I am inclined to think that all these effects were produced merely by the violent concussion of the atmosphere.

"We proceeded into the garden while the noise still continued, and appeared to be in a perpendicular direction above us. Some time after, when it had ceased, we heard a hollow noise, which seemed to roll along the

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the chain of the Pyrenees in echoes, for the distance of 15 miles. It continued about four minutes, becoming gradually more remote, and always weaker; and at the same time we perceived a strong smell of sulphur.

“While we were endeavouring to point out to some persons present the place where the meteor had divided itself, we observed a small whitish cloud, which arose perhaps from the vapour of it, and which concealed from us the three stars of the Great Bear, lying in the middle of those forming the semicircle. With some difficulty, however, we could at last distinguish these stars again behind the thin cloud. There arose, at the same time, a fresh gentle breeze.

“From the time that elapsed between the bursting of the ball and the explosion which followed, I was inclined to think that the meteor was at the height of at least seven or eight miles, and that it fell four miles to the north of Mormes. The latter part of my conjecture was soon confirmed by an account which we received, that a great many stones had fallen from the atmosphere at Juliac, and in the neighbourhood of Barbotan. One of these places lies at the distance of about four miles to the north of Mormes, and the other at about the distance of five to the north-north-west.”

M. de Carrits Barbotan, the friend who was with the Professor in the court and garden of Mormes when the meteor first attracted their attention, was at Juliac two days afterwards, and confirmed to him the truth of this circumstance. It appeared, likewise, from the account of several intelligent persons, highly worthy of credit, that the meteor burst at a little distance from Juliac, and that the stones which fell were found lying in a space almost circular, about two miles in diameter. They were of various sizes. Some were *seen to fall*, which, when found, weighed 18 or 20 pounds, and which had sunk into the earth from two to three feet. M. de C. Barbaton transmitted one weighing 18 pounds to the Academy of Sciences at Paris; and M. Bandin was told, that some were found which weighed even 50 pounds. He examined a small one, and found it very heavy in proportion to its size: it was black on the outside; of a greyish colour in the inside, and interspersed with a number of small shining metallic particles. On striking it with a piece of steel, it produced a few small dark red sparks, not very lively. A mineralogist, to whom a like piece of stone from the same meteor was shewn at Paris, described it as a kind of grey slag mixed with calcareous spar, the surface of which exhibited vitrified blackish calx of iron. The Professor was told also, that some stones were found totally vitrified.

Such (says Dr Chladni) is the account given by Baudin of this meteor; the phenomena of which he endeavours to explain from accumulations in the upper parts of the atmosphere.

According to all the observations hitherto made with any accuracy on fire-balls, the height at which they were first perceived was always very considerable, and by comparing the angles under which they were seen from different points, often 19 German miles, and even more; their velocity, for the most part, several miles in a second; and their size always very great, often a quarter of a mile, and even more, in diameter. They were all seen to fall mostly in an oblique direction; not

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one of them ever proceeded upwards. All of them have appeared under the form of a globular mass, sometimes a little extended in length, and highly luminous; having behind it a tail, which, according to every appearance, was composed of flames and smoke. All of them burst after they were seen to move through a large space, sometimes over several districts, with an explosion which shook every thing around. In every instance where there has been an opportunity of observing the fragments that fell after they burst, and which sometimes have sunk to the depth of several feet into the earth, they were found to consist of scorious masses, which contained iron in a metallic or calcined state, pure, or else mixed with different kinds of earth and sulphur. All the ancient and modern accounts, written partly by naturalists and partly by others, are so essentially similar, that the one seems to be only a repetition of the other. This conformity in accounts, the authors of which knew nothing of those given by others, and who could have no interest in fabricating similar tales, can scarcely have arisen from accident or fiction, and gives to the related facts, however inexplicable many of them may seem, every degree of credibility.

In the third volume of Pallas's Travels, we have an account of a mass of iron discovered by him in Siberia; which Dr Chladni considers as having been undoubtedly a fire-ball, or the fragment of a fire-ball. This problematical mass was found between Krasnojarsk and Abekansk in the high slate mountains, quite open and uncovered. It weighed 1600 pounds; had a very irregular and somewhat compressed figure like a rough granite; was covered externally with a ferruginous kind of crust; and the inside consisted of malleable iron, brittle when heated, porous like a large sea sponge, and having its interstices filled with a brittle hard vitrified substance of an amber yellow colour. This texture and the vitrified substance appeared uniformly throughout the whole mass, and without any traces of slag or artificial fire.

Dr Chladni shews, with a great deal of ingenuity, that this mass neither originated by the wet method, nor could have been produced by art, the burning of a forest, by lightning, or by a volcanic eruption. It appears to him, therefore, in the highest degree probable, that it is of the same nature with fire-balls, or, as they have sometimes been called, *flying dragons*. The Tartars, as we are informed by Pallas, considered this mass as a sacred relic which had dropped down from heaven; and this circumstance Dr Chladni considers as no slight confirmation of his opinion, which he farther supports by the following reasonings:

“1. As fire-balls consist of dense and heavy substances, which, by their exceedingly quick movement, and the friction thence excited by the atmosphere, become electric, are reduced to a state of ignition, and melted by the heat, so that they extend to a great size, and burst; it thence follows, that in places where fragments, produced by the bursting of a fire-ball, have been found, substances endowed with all these properties must also have been found. Iron, however, the principal component part of all the masses hitherto found (and he speaks of many besides that of Pallas), possesses all these properties in a very eminent degree. The weight and toughness of the principal component parts of fire-balls, which

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which must be very considerable, since, with the greatest possible dilitation, they retain consistence enough to proceed with the utmost velocity through such an immense space without decomposition of their mass, and without their progress being obstructed by the resistance of the air, agree perfectly well with melted iron; their dazzling white light has by many observers been compared to that of melted iron; iron also exhibits the same appearances of flaming, smoking, and throwing out sparks, and all these phenomena are most beautiful when they take place in vital air. Of the extension by elastic fluids expanded by the heat, and of the contraction which follows from cold, traces may be discovered in the internal spongy nature of the iron masses which have been found, and in the globular depressions of the exterior hard crust; the latter of which gives us reason to suppose, that in these places there have been air-bubbles, which, on cooling, sunk down. The mixture of sulphur found in various masses, agrees also exceedingly well with the phenomena of fire-balls, and especially with the great inflammability of sulphur in very thin impure air; for it is well known that sulphur in an air-pump will take fire in air in which few other bodies could do the same. In regard to those masses in which no sulphur was found, this may have arisen from the sulphur escaping in vapour, since some time after the appearance of fire-balls a strong smell of sulphur has been perceived. The brittleness of the Siberian iron mass when heated, may arise from some small remains of sulphur, which may perhaps be the cause of the facility with which fragments of this mass, as well as of another found at Aix-la-Chapelle, could be roasted.

“2. The whole texture of the masses betrayed evident signs of fusion. This, however, cannot have been occasioned by any common, natural, or artificial fire; and particularly for this reason, because iron so malleable is not fusible in such fire, and when it is fused with the addition of inflammable matters, loses its malleability, and becomes like common raw iron. The vitrified substance in the Siberian mass is equally incapable of being fused in a common fire. The fire, then, must have been much stronger than that produced by the common, natural, and artificial means; or the fusion must have been effected by the force of exceedingly strong electricity; or perhaps both causes may have been combined together.

“3. It is totally incomprehensible how, on the high slate mountains, where the Siberian mass was found, at a considerable distance from the iron mines; in the chalky soil of the extensive plains of America, where for a hundred miles around there are no iron mines, and not even so much as a stone to be found; and at Aix-la-Chapelle, where, as far as the author knows, there are no iron works—so many ferruginous particles could be collected in a small space as would be necessary to form masses of 1600, 15,000, and 17,000, up to 33,600 pounds. This circumstance shews that these masses could as little have been fused by lightning as by the burning of a forest or of fossil coal. These masses were found quite exposed and uncovered, and not at any depth in the earth, where we can much more readily admit such an accumulation of ferruginous particles to have been melted by the effects of lightning.

“Should it be asked how such masses originated, or

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by what means they were brought into such an insulated position? this question would be the same as if it were asked how the planets originated. Whatever hypotheses we may form, we must either admit that the planets, if we except the many revolutions which they may have undergone, either on or near their surface, have always been since their first formation, and ever will be the same; or that Nature, acting on created matter, possesses the power to produce worlds and whole systems, to destroy them, and from their materials to form new ones. For the latter opinion there are, indeed, more grounds than for the former, as alternations of destruction and creation are exhibited by all organised and unorganised bodies on our earth; which gives us reason to suspect that Nature, to which greatness and smallness, considered in general, are merely relative terms, can produce more effects of the same kind on a larger scale. But many variations have been observed on distant bodies, which, in some measure, render the last opinion probable. For example, the appearing and total disappearing of certain stars, when they do not depend upon periodical changes. If we now admit that planetary bodies have started into existence, we cannot suppose that such an event can have otherwise taken place, than by conjecturing that either particles of matter, which were before dispersed through infinite space in a more soft and chaotic condition, have united together in large masses by the power of attraction; or that new planetary bodies have been formed from the fragments of much larger ones that have been broken to pieces, either perhaps by some external shock, or by an internal explosion. Let whichever of these hypotheses be the truest, it is not improbable, or at least not contrary to nature, if we suppose that a large quantity of such material particles, either on account of their too great distance, or because prevented by a stronger movement in another direction, may not have united themselves to the larger accumulating mass of a new world; but have remained insulated, and, impelled by some shock, have continued their course through infinite space, until they approached so near to some planet as to be within the sphere of its attraction, and then by falling down to occasion the phenomena before mentioned.”

Whether Chladni be a philosopher of the French school we know not; but some parts of his theory tend strongly towards materialism; and the arguments by which he attempts to prop those parts are peculiarly weak. When he talks of *Nature* producing worlds, he either substitutes *Nature* for *Nature's God*, or utters jargon which has no meaning. In what sense the word *Nature* is used by every philosopher of a sound mind, we have elsewhere been at some pains to shew (see RIVER, n° 116. *Encycl.*); but how absurd would it be to say, that the system of general laws, by which the Author and Governor of the universe connects together its various parts, and regulates all their operations, possesses, independently of Him, “the power to produce worlds and whole systems, to destroy them, and from their materials to form new ones!”

As Chladni admits, or talks as if he admitted, the creation of matter, it would be wrong to impute to him this absurdity; but if by *Nature* he means *God*, and he can consistently mean nothing else, we beg leave to affirm, that it is *directly contrary* to every notion which

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which we can form of Nature in *this sense*, "to suppose that a large quantity of material particles, either on account of the *distance*, or because prevented by a *stronger movement* in another direction, have not united themselves to the larger accumulating mass of a new world, but remained insulated, and impelled by some shock, have continued their course through infinite space, &c." Is there any distance to which God cannot reach, or any movement so strong as to resist his power? Our author's language is indeed confused, and probably his ideas were not very clear. When he speaks of the particles of matter being at first dispersed through infinite space, and afterwards united by the power of attraction, he revives the question which was long ago discussed between Newton and Bentley, and discussed in such a manner as should have silenced for ever the babblings of those who form worlds by attraction.

"The hypothesis (says Newton) of matter's being at first evenly spread through the heavens, is, in my opinion, inconsistent with the hypothesis of innate gravity without a supernatural power to reconcile them; and therefore infers a Deity. For if there be innate gravity, it is impossible now for the matter of the earth, and all the planets and stars, to fly up from them, and become evenly spread through all the heavens, without a supernatural power; and certainly that which can never be hereafter without a supernatural power, could never be heretofore without the same power." Dr Chladni, indeed, does not say that his particles of matter were evenly dispersed through infinite space; but such must be his meaning, if he has any meaning: for matter unevenly dispersed must, by an innate attraction, be united as soon as it exists, and so united as not to leave small fragments of it to wander, we know not why, through the trackless void. Turn matter on all sides, make it eternal or of late production, finite or infinite, there can be no regular system produced but by a voluntary and meaning agent; and therefore, if it be true that fire-balls are masses of dense matter, coeval with the planetary system, existing in the celestial regions, and thence conveyed to our earth, they must have been formed, and their motions impressed upon them, by the Author of Nature for some wise purpose, though by us that purpose may never be discovered. One thing seems pretty clear, that wherever they may be formed, the phenomena attending their bursting, account sufficiently for the notions of thunderbolts which have been generally entertained in all ages, and in every country.

Greek-Fire (see *Wild-Fire*, *Encycl.*). In the second volume of Mr Nicholson's Philosophical Journal, we have the following receipt for making this composition, taken from some manuscripts of Leonard de Vinci, who flourished in the end of the fifteenth and beginning of the sixteenth centuries, and who appears to have advanced far before his contemporaries in physical science. Take the charcoal of willow, nitre, brandy, resin, sulphur, pitch, and camphor. Mix the whole together over the fire. Plunge a woollen cord in the mixture, and form it into balls, which may afterwards be provided with spikes. These balls, being set on fire, are thrown into the enemy's vessels. It is called the Greek fire, and is a singular composition, for it burns even upon the water. Callinicus the architect taught this composition to the Romans (of Constantinople), who derived great advantage from it, particularly under the

emperor Leo, when the Orientals attacked Constantinople. A great number of their vessels were burned by means of this composition.

The composition of the Greek fire thus given by Vincini is found in nearly the same words in some of the writings of Baptista Porta; whence it appears that both authors derived their information from the same source. A composition which burnt without access to the atmosphere could not fail to fill the minds of our forefathers with wonder; but the modern discoveries in chemistry have disclosed the secret, by shewing, that the combustion is carried on by means of the oxygen contained in the nitre.

Rasant or *Rasant Fire*, is a fire from the artillery and small arms, directed parallel to the horizon, 'or to those parts of the works of a place that are defended.

Running Fire is when ranks of men fire one after another; or when the lines of an army are drawn out to fire on account of a victory; in which case each squadron or battalion takes the fire from that on its right, from the right of the first line to the left, and from the left to the right of the second line, &c.

FISHING, the art of catching fish. See **ANGLING**, **FISHERY**, and **FISHING**, &c. *Encycl.*

Chinese FISHING. We venture to give this appellation to some very ingenious contrivances of the people of China for catching in their lakes, not only fish, but water-fowl. For the purpose of catching fish they have trained a species of pelican, resembling the common corvorant, which they call the *Leu-tze*, or fishing-bird. It is brown, with a white throat, the body whitish beneath, and spotted with brown; the tail is rounded, the irides blue, and the bill yellow. Sir George Staunton, who, when the embassy was proceeding on the southern branch of the great canal, saw these birds employed, tells us, that on a large lake, close to the east side of the canal, are thousands of small boats and rafts, built entirely for this species of fishery. On each boat or raft are ten or a dozen birds, which, at a signal from the owner, plunge into the water; and it is astonishing to see the enormous size of fish with which they return, grasped within their bills. They appeared to be so well trained, that it did not require either ring or cord about their throats to prevent them from swallowing any portion of their prey, except what their master was pleased to return to them for encouragement and food. The boat used by these fishermen is of a remarkable light make, and is often carried to the lake, together with the fishing birds, by the men who are there to be supported by it.

The same author saw the fishermen busy on the great lake Wee-chaung-hee; and he gives the following account of a very singular method practised by them for catching the fish of the lake without the aid of birds, of net, or of hooks.

To one side of a boat a flat board, painted white, is fixed, at an angle of about 45 degrees, the edge inclining towards the water. On moonlight nights the boat is so placed that the painted board is turned to the moon, from whence the rays of light striking on the whitened surface, give to it the appearance of moving water; on which the fish being tempted to leap as on their element, the boatmen, rising with a string the board, turn the fish into the boat.

Water-fowl are much sought after by the Chinese and

Fire,
Fishing.

Fistula. and are taken upon the same lake by the following ingenious device. Empty jars or gourds are suffered to float about upon the water, that such objects may become familiar to the birds. The fisherman then wades into the lake with one of those empty vessels upon his head, and walks gently towards a bird; and lifting up his arm, draws it down below the surface of the water without any disturbance or giving alarm to the rest, several of whom he treats in the same manner, until he fills the bag he had brought to hold his prey. The contrivance itself is not so singular, as it is that the same exactly should have occurred in the new continent, as Ulloa asserts, to the natives of Carthagena, upon the lake Ciénega de Teñas.

FISTULA LACHRYMALIS is a disease which, in all its stages, has been treated of in the article **SURGERY**, chap. xiv. *Encycl.* A work, however, has been lately published by **JAMES WARE** surgeon, in which there is the description of an operation for its cure considerably different from that most commonly used, and which, while it is simple, the author's experience has ascertained to be successful.

In the cure of this disease, which is very troublesome, and not very uncommon, it is a well known practice to insert a metallic tube in the nasal duct of the lachrymal canal: but the advantage derived from this operation is not at all times lasting. Among other causes of failure, Mr Ware notices the lodgment of inspissated mucus in the cavity of the tube. To remedy this defect, he recommends the following operation.

“ If the disease has not occasioned an aperture in the lachrymal sac, or if this aperture be not situated in a right line with the longitudinal direction of the nasal duct, a puncture should be made into the sac, at a small distance from the internal juncture of the palpebræ, and nearly in a line drawn horizontally from this juncture towards the nose with a spear-pointed lancet. The blunt end of a silver probe, of a size rather smaller than the probes that are commonly used by surgeons, should then be introduced through the wound, and gently, but steadily, pushed on in the direction of the nasal duct, with a force sufficient to overcome the obstruction in this canal, and until there is reason to believe that it has freely entered into the cavity of the nose. The position of the probe, when thus introduced, will be nearly perpendicular; its side will touch the upper edge of the orbit; and the space between its bulbous end in the nose and the wound in the skin will usually be found, in a full-grown person, to be about an inch and a quarter, or an inch and three-eighths. The probe is then to be withdrawn, and a silver style, of a size nearly similar to that of the probe, but rather smaller, about an inch and three-eighths in length, with a flat head, like that of a nail, but placed obliquely, that it may fit close on the skin, is to be introduced through the duct, in place of the probe, and to be left constantly in it. For the first day or two after the style has been introduced, it is sometimes advisable to wash the eye with a weak saturnine lotion, in order to obviate any tendency to inflammation which may have been excited by the operation; but this in general is so slight, that our author has rarely had occasion to use any application to remove it. The style should be withdrawn once every day for about a week, and afterwards every second or third day. Some warm water

should each time be injected through the duct into the nose, and the instrument be afterwards replaced in the same manner as before. Mr Ware formerly used to cover the head of the style with a piece of diachylon plaster spread on black silk, but has of late obviated the necessity for applying any plaster by blackening the head of the style with sealing wax.

“ The effect (says he) produced by the style, when introduced in the way above mentioned, at first gave me much surprise. It was employed with a view similar to that with which Mr Pott recommends the introduction of a bougie; viz. to open and dilate the nasal duct, and thus to establish a passage, through which the tears might afterwards be conveyed from the eye to the nose. I expected, however, that whilst the style continued in the duct the obstruction would remain, and of course that the watering of the eye, and the weakness of the sight, would prove as troublesome as they had been before the instrument was introduced. I did not imagine that any essential benefit could result from the operation until the style was removed, and the passage thereby opened. It was an agreeable disappointment to me to find that the amendment was much more expeditious. The watering of the eye almost wholly ceased as soon as the style was introduced; and in proportion as the patient amended in this respect, his sight also became more strong and useful. The style, therefore, seems to act in a twofold capacity: first, it dilates the obstructed passage; and then, by an attraction somewhat similar to that of a capillary tube, it guides the tears through the duct into the nose.

“ The wound that I usually make into the sac, if the suppurative process has not formed a suitable aperture in this part, is no larger than is just sufficient to admit the end of the probe or style; and this, in general, in a little time, becomes a fistulous orifice, through which the style is passed without occasioning the smallest degree of pain. The accumulation of matter in the lachrymal sac, which, previous to the operation, is often copious, usually abates soon after the operation has been performed; and, in about a week or ten days, the treatment of the case becomes so easy, that the patient himself, or some friend or servant who is constantly with him, is fully competent to do the whole that is necessary. It consists solely in withdrawing the style two or three times in the week, occasionally injecting some warm water, and then replacing the instrument in the same way in which it was done before.

“ It is not easy to ascertain the exact length of time that the style should be continued in the duct. Some have worn it many years, and, not finding any inconvenience from the instrument, are still afraid and unwilling to part from it. Others, on the contrary, have disused it at the end of about a month or six weeks, and have not had the smallest return of the obstruction afterwards.”

The author relates so many successful cases of this operation, that we thought it our duty to record his method in this Supplementary volume of our general repository of arts and sciences; for a successful practice, as well in surgery as in physic, must rest on the basis of experience.

OBLIQUE or **SECOND FLANK**, or *FLANK of the Curtain*, is that part of the curtain from whence the face of the opposite bastion can be seen, being contained between the lines rasant and sissant, or the greater

*Fistula,
Flank.*

Flank
||
Floating.

and less lines of defence; or the part of the curtain between the flank and the point where the schanze line of defence terminates.

Covered, Low, or Retired FLANK, is the platform of the casemate, which lies hid in the bastion, and is otherwise called the *orillon*.

Schanze FLANK, is that from whence a cannon playing, fires directly on the face of the opposite bastion.

Rasant or Razant FLANK, is the point from whence the line of defence begins, from the conjunction of which with the curtain the shot only raseth the face of the next bastion, which happens when the face cannot be discovered but from the flank alone.

FLIE or FLY, that part of the mariner's compass on which the thirty-two points of the wind are drawn, and over which the needle is placed, and fastened underneath.

FLOATING BODIES are such as swim on the surface of a fluid, of which the most important are ships, and all kinds of vessels employed in war and in commerce. Every seaman knows of how much consequence it is to determine the stability of such vessels, and the positions which they assume when they float freely and at rest on the water. To accomplish this, it is necessary to state the principles on which that stability and these positions depend; and this has been done with so much ingenuity and science by **GEORGE ATWOOD, Esq; F. R. S.** in the Philosophical Transactions for the year 1796, that we are persuaded a large class of our readers will thank us for inserting an abstract of his memoir in this place.

A floating body is pressed downwards by its own weight in a vertical line that passes through its centre of gravity; and it is sustained by the upward pressure of a fluid, acting in a vertical line that passes through the centre of gravity of the immersed part; and unless these two lines be coincident, so that the two centres of gravity may be in the same vertical line, the solid will revolve on an axis, till it gains a position in which the equilibrium of floating will be permanent. Hence it appears, that it is necessary, in the first place, to ascertain the proportion of the part immersed to the whole; for which purpose the specific gravity of the floating body must be known; and then it must be determined, by geometrical or analytical methods, in what positions the solid can be placed on the surface of the fluid, so that the two centres of gravity already mentioned may be in the same vertical line when a given part of the solid is immersed under the surface of the fluid. When these preliminaries are settled, something still remains to be done. Positions may be assumed in which the circumstances just recited concur, and yet the solid will assume some other position in which it will permanently float. If a cylinder, *e. g.* having its specific gravity to that of the fluid on which it floats as 3 to 4, and its axis to the diameter of the base as 2 to 1, be placed on the fluid with its axis vertical, it will sink to a depth equal to a diameter and a half of the base; and while its axis is preserved in a vertical position by external force, the centres of gravity of the whole solid and of the immersed part will remain in the same vertical line: but when the external force that sustained it is removed, it will decline from its upright position, and will permanently float with its axis horizontal. If the axis be supposed to be half of the dia-

meter of the base, and be placed vertically, the solid will sink to the depth of three eighths of its diameter; and in that position it will float permanently. If the axis be made to incline to the vertical line, the solid will change its position until it settles permanently with the axis perpendicular to the horizon.

Whether, therefore, a solid floats permanently, or oversets when placed on the surface of a fluid, so that the centre of gravity of the solid and that of the part immersed shall be in the same vertical line, it is said to be in a position of equilibrium; and of this equilibrium there are three species, *viz.* the equilibrium of stability, in which the solid floats permanently in a given position; the equilibrium of instability, in which the solid, though the two centres of gravity already mentioned are in the same vertical line, spontaneously oversets, unless supported by external force; and the equilibrium of indifference, or the insensible equilibrium, in which the solid rests on the fluid indifferent to motion, without tendency to right itself when inclined, or to incline itself farther.

If a solid body floats permanently on the surface of a fluid, and external force be applied to incline it from its position, the resistance opposed to this inclination is termed the stability of floating. Among various floating bodies, some lose their quiescent position, and some gain it, after it has been interrupted, with greater facility and force than others.

Some ships at sea (*e. g.*) yield to a given impulse of the wind, and suffer a greater inclination from the perpendicular than others. As this resistance to heeling or pitching, duly regulated, has been deemed of importance in the construction of vessels, several eminent mathematicians have investigated rules for determining the stability of ships from their known dimensions and weight, without recurring to actual trial. To this class we may refer Bouguer, Euler, Fred. Chapman, and others; who have laid down theorems for this purpose, founded on a supposition that the inclinations of ships from their quiescent positions are evanescent, or, in a practical sense, very small.

“But ships at sea (says our ingenious author) are known to heel through angles of 10° , 20° , or even 30° ; and therefore a doubt may arise how far the rules, demonstrated on the express condition that the angles of inclination are of evanescent magnitude, should be admitted as practical; applicable in cases where the inclinations are so great.”—“If we admit that the theory of statics can be applied with any effect to the practice of naval architecture, it seems to be necessary that the rules, investigated for determining the stability of vessels, should be extended to those cases in which the angles of inclination are of any magnitude likely to occur in the practice of navigation.”

A solid body placed on the surface of a lighter fluid, at the depth corresponding to the relative gravities, cannot change its position by the combined actions of its weight and the pressure of the fluid, except by revolving on some horizontal axis which passes through the centre of gravity: but as many axes may be drawn through this point of the floating body in a direction parallel to the horizon, and the motion of the solid respects one axis only, this axis must be determined by the figure of the body and the particular nature of the case. When this axis of motion, as it is called, is determined,

Floating.

Floating. terminated, and the specific gravity of the solid is known, "the positions of permanent floating will be obtained, first by finding the several positions of equilibrium through which the solid may be conceived to pass, while it revolves round the axis of motion; and secondly, by determining in which of those positions the equilibrium is permanent, and in which of them it is momentary and unstable."

Such as we have now briefly stated are the general principles on which are founded Mr Atwood's investigations for determining the positions assumed by homogeneous bodies, floating on a fluid surface; and also for determining the stability of ships and of other floating bodies. We cannot farther accompany him in his elucidation of them, in the problems to the solution of which they lead, and in the important practical purposes of naval architecture to which they are referred. The whole paper, comprehending no less than 85 pages, is curious and valuable; it abounds with analytical and geometrical disquisitions of the most elaborate kind; and it serves to enlarge our acquaintance with a subject that is not only highly interesting to the speculative mathematician, but extremely useful in its practical application.

With this latter view, the author seems to have directed his attention to the various objects of inquiry which this article comprehends. They are such as intimately relate to the theory of naval architecture, so far as it depends on the pure laws of mechanics, and they contribute to extend and improve this theory. The union of those principles that are deduced from the laws of motion, with the knowledge which is derived from observation and experience, cannot fail to establish the art of constructing vessels on its true basis, and gradually to lead to farther improvements of the greatest importance and utility. To this purpose, the author observes, that

"If the proportions and dimensions adopted in the construction of individual vessels are obtained by exact geometrical mensurations, and calculations founded on them, and observations are made on the performance of these vessels at sea; experiments of this kind, sufficiently diversified and extended, seem to be the proper grounds on which theory may be effectually applied in developing and reducing to system those intricate, subtil, and hitherto unperceived causes, which contribute to impart the greatest degree of excellence to vessels of every species and description. Since naval architecture is reckoned amongst the practical branches of science, every voyage may be considered as an experiment, or rather as a series of experiments, from which useful truths are to be inferred towards perfecting the art of constructing vessels: but inferences of this kind, consistently with the preceding remark, cannot well be obtained, except by acquiring a perfect knowledge of all the proportions and dimensions of each part of the ship; and secondly, by making and recording sufficiently numerous observations on the qualities of the vessel, in all the varieties of situation to which a ship is usually liable in the practice of navigation."

In the valuable miscellany entitled the *Philosophical Magazine*, there is a paper on this subject by Mr John George English, teacher of mathematics and mechanical philosophy; which, as it is not long, and is easily understood, we shall take the liberty to transcribe.

Floating. "However operose and difficult the calculations necessary to determine the stability of nautical vessels may, in some cases, be, yet they all depend, says this author, upon the four following simple and obvious theorems, accompanied with other well-known stereometrical and statical principles.

"*Theorem 1.* Every floating body displaces a quantity of the fluid in which it floats, equal to its own weight: and consequently, the specific gravity of the fluid will be to that of the floating body, as the magnitude of the whole is to that of the part immersed.

"*Theorem 2.* Every floating body is impelled downward by its own essential power, acting in the direction of a vertical line passing through the centre of gravity of the whole; and is impelled upward by the reaction of the fluid which supports it, acting in the direction of a vertical line passing through the centre of gravity of the part immersed: therefore, unless these two lines are coincident, the floating body thus impelled must revolve round an axis, either in motion or at rest, until the equilibrium is restored.

"*Theorem 3.* If by any power whatever a vessel be deflected from an upright position, the perpendicular distance between two vertical lines passing through the centres of gravity of the whole, and of the part immersed respectively, will be as the stability of the vessel, and which will be positive, nothing, or negative, according as the metacentre is above, coincident with, or below, the centre of gravity of the vessel.

"*Theorem 4.* The common centre of gravity of any system of bodies being given in position, if any one of these bodies be moved from one part of the system to another, the corresponding motion of the common centre of gravity, estimated in any given direction, will be to that of the aforesaid body, estimated in the same direction, as the weight of the body moved is to that of the whole system.

"From whence it is evident, that in order to ascertain the stability of any vessel, the position of the centres of gravity of the whole, and of the part immersed, must be determined; with which, and the dimensions of the vessel, the line of floatation, and angle of deflection, the stability or power either to right itself or overturn, may be found.

"In ships of war and merchandise, the calculations necessary for this purpose become unavoidably very operose and troublesome; but they may be much facilitated by the experimental method pointed out in the New Transactions of the Swedish Academy of Sciences, first quarter of the year 1787, page 48.

"In river and canal boats, the regularity and simplicity of the form of the vessel itself, together with the compact disposition and homogeneous quality of the burden, render that method for them unnecessary, and make the requisite calculations become very easy. Vessels of this kind are generally of the same transverse section throughout their whole length, except a small part in prow and stern, formed by segments of circles or other simple curves; therefore a length may easily be assigned such, that any of the transverse sections being multiplied thereby, the product will be equal to the whole solidity of the vessel. The form of the section ABCD is for the most part either rectangular, as in fig. 1. trapezoidal as in fig. 2. or mix-

Floating. tilineal as in fig. 3. in all which MM represents the line of floatation when upright, and EF that when inclined at any angle MXE; also G represents the centre of gravity of the whole vessel, and R that of the part immersed.

“ If the vessel be loaded quite up to the line AB, and the specific gravity of the boat and burden be the same, then the point G is simply the centre of gravity of the section ABCD; but if not, the centres of gravity of the boat and burden must be found separately, and reduced to one by the common method, namely, by dividing the sum of the momenta by the sum of weights, or areas, which in this case are as the weights. The point R is always the centre of gravity of the section MMCD, which, if consisting of different figures, must also be found by dividing the sum of the momenta by the sum of the weights as common. These two points being found, the next thing necessary is to determine the area of the two equal triangles MXE, MXF, their centres of gravity *o, o*, and the perpendicular projected distance *nn* of these points on the water line EF. This being done, through R, and parallel to EF, draw RΓ = a fourth proportional to the whole area MMCD, either triangle MXE or MXF, and the distance *nn*; through T, and at right angles to RT or EF, draw TS meeting the vertical axis of the vessel in S the metacentre; also through the points G, B, and parallel to ST, draw NGW and BV; moreover through S, and parallel to EF, draw WSV, meeting the two former in V and W; then SW is as the stability of the vessel, which will be positive, nothing, or negative, according as the point S is above, coincident with, or below, the point G. If now we suppose W to represent the weight of the whole vessel and burden (which will be equal to the section MMCD multiplied by the length of the vessel), and P to represent the required weight applied at the gunwale B to sustain the vessel at the given angle of inclination; we shall always have this proportion: as VS : SW :: W : P; which proportion is general, whether SW be positive or negative; it must only, in the latter case, be supposed to act upward to prevent an overturn.

“ In the rectangular vessel, of given weight and dimensions, the whole process is so evident, that any farther explanation would be unnecessary. In the trapezoidal vessel, after having found the points G and R, let AD, BC be produced until they meet in K. Then, since the two sections MMCD, EFDC are equal, the two triangles MMK, EFK are also equal; and therefore the rectangle EK × KF = KM × KM = KM²; and since the angle of inclination is supposed to be known, the angles at E and F are given. Consequently, if a mean proportional be found between the sines of the angles at E and F, we shall have the following proportions:

“ As the mean proportional thus found : sine ∠ E :: KM : KF, and as the said mean proportional : sine ∠ F :: KM : KE; therefore ME, MF become known; from whence the area of either triangle MXE or MXF, the distance *nn*, and all the other requisites, may be found.

“ In the mixtilineal section, let AB = 9 feet = 108 inches, the whole depth = 6 feet = 72 inches, and the altitude of MM the line of floatation 4 feet or 48 inches; also let the two curvilinear parts be circular

quadrants of two feet, or 24 inches radius each. Then the area of the two quadrants = 904.7808 square inches, and the distance of their centres of gravity from the bottom = 13.8177 inches very nearly; also the area of the included rectangle *abie* = 1440 square inches, and the altitude of its centre of gravity 12 inches; in like manner, the area of the rectangle *ABcd* will be found = 5184 square inches, and the altitude of its centre of gravity 48 inches: therefore we shall have

Momentum of the two quad.	}	= 904.7808 × 13.8177 = 12501.98566016
Moment. of the rektan. <i>abie</i>		
Moment. of the rektan. <i>ABcd</i>	}	= 5184 × 48 = 248832
		75287808
		278613.98966016

“ Now the sum of the momenta, divided by the sum of the areas, will give $\frac{278613.98966016}{7528.7808} = 37.006$ inches, the altitude of G, the centre of gravity of the section ABCD above the bottom. In like manner, the altitude of R, the centre of gravity of the section MMCD, will be found to be equal $\frac{123093.98966016}{4936.7808} = 24.934$ inches; and consequently their difference, or the value of GR = 12.072 inches, will be found.

Suppose the vessel to heel 15°, and we shall have the following proportion; namely, As radius : tangent of 15° :: MX = 54 inches : 14.469 inches = ME or MF; and consequently the area of either triangle MXE or MXF = 390.663 square inches. Therefore, by theorem 4th, as 4936.7808 : 390.663 :: 72 = *nn* = $\frac{2}{3}$ AB : 5.6975 inches = RT; and, again, as radius : sine of 15° :: 12.072 = GR : 3.1245 inches = RN; consequently RT - RN = 5.6975 - 3.1245 = 2.573 inches = SW, the stability required.

“ Moreover, as the sine of 15° : radius :: 5.6975 = RT : 22.013 = RS, to which, if we add 24.934, the altitude of the point R, we shall have 46.947 for the height of the metacentre, which taken from 72, the whole altitude, there remains 25.053; from which, and the half width = 54 inches, the distance BS is found = 59.529 inches very nearly, and the angle SBV = 80° - 06' - 42"; from whence SV = 58.645 inches.

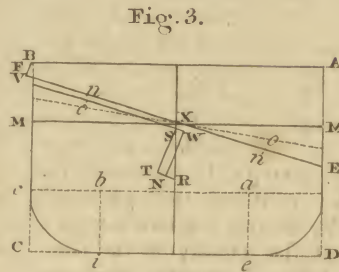
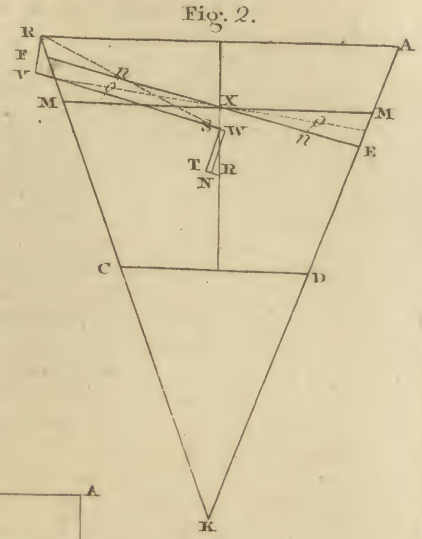
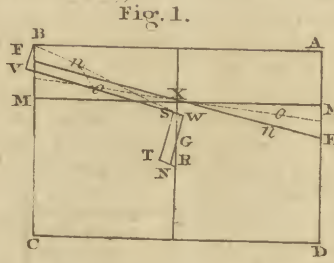
Again: Let us suppose the mean length of the vessel to be 40 feet, or 480 inches, and we shall have the weight of the whole vessel equal to the area of the section MMCD = 4936.7808 multiplied by 480 = 2369654.784 cubic inches of water, which weighs exactly 85708 pounds avoirdupois, allowing the cubic foot to weigh 62.5 pounds.

“ And, finally, as SV : SW (*i. e.*) as 58.645 : 2.573 :: 85708 : 3760 +, the weight on the gunwale which will sustain the vessel at the given inclination. Therefore a vessel of the above dimensions, and weighing 38 tons, 5 cwts. 28 lbs. will require a weight of 1 ton, 13 cwts. 64 lbs. to make her incline 15°.

“ In this example, the deflecting power has been supposed to act perpendicularly on the gunwale at B; but if the vessel is navigated by sails, the centre velique must be found; with which, and the angle of deflection, the projected distance thereof on the line SV may be obtained; and then the power, calculated as above necessary

Floating.

FLOATING BODIES



EUPHORBIA

Fig. 1.



Fig. 2.



Fig. 3.



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Fluent
||
Fordyce.

Fordyce.

necessary to be applied at the projected point, will be that part of the wind's force which causes the vessel to heel. And conversely, if the weight and dimensions of the vessel, the area and altitude of the sails, the direction and velocity of the wind be given, the angle of deflection may be found."

FLUENT, or **FLOWING QUANTITY**, in the doctrine of fluxions, is the variable quantity which is considered as increasing and decreasing; or the fluent of a given fluxion, is that quantity whose fluxion being taken, according to the rules of that doctrine, shall be the same with the given fluxion. See **FLUXIONS**, *Encycl.*

FLUIDS (MOTION IN). See **HYDROSTATICS** and **RESISTANCE OF FLUIDS**, *Encycl.* and **MOTION** in this *Supplement*.

FOGEDAR, the military governor of a subordinate district in India, who has sometimes the additional office of collecting the revenues.

FOLIATE, a name given by some to a curve of the 2d order, expressed by the equation $x^3 + y^3 = axy$, being one species of defective hyperbolas, with one asymptote, and consisting of two infinite legs crossing each other, forming a sort of leaf. It is the 42d species of Newton's Lines of the 3d Order.

FORCER, in mechanics, is properly a piston without a valve. For, by drawing up such a piston, the air is drawn up, and the water follows; then pushing the piston down again, the water, being prevented from descending by the lower valve, is forced up to any height above, by means of a side branch between the two.

FORDYCE (James, D. D.), so well known to serious readers by his sermons to young women, and other specimens of pulpit eloquence, was born at Aberdeen in the year 1720. His father was a man much esteemed, and held, more than once, the office of chief magistrate in his native city; and his mother was a woman of good sense, amiable temper, and exemplary piety. This respectable pair had the singular felicity of transmitting superior talents to almost every individual of a numerous family; of one of which, viz. David Fordyce, the reader will find some account in the *Encyclopaedia*.

The subject of this memoir, who was their fourth son, acquired, as well as his brother, the rudiments of classical learning at the grammar school of Aberdeen, whence he was removed to the Marischal college and university in the same city. Having completed a regular course of study both in philosophy and theology, he was licensed, when very young, according to the forms of the church of Scotland, to be a preacher of the gospel; and was soon afterwards preferred to the place of second minister in the collegiate church of Brechin in the county of Angus. After remaining there for some years, he received a presentation to the church of Alloa near Stirling; and though the inhabitants of that parish were prepossessed in favour of another minister whom they knew, and prejudiced against Mr Fordyce whom they did not know; so narrow minded and totally destitute of taste was his colleague in Brechin, that he judged it expedient to hazard the consequences of a removal. He was aware that he entered on his new charge under a considerable degree of popular odium; but he thought it more probable

that he should be able to overcome that odium, than conciliate the affections of a four fanatic. In this expectation he was not deceived. The prejudices of the good people in Alloa were very quickly removed, not more by the able and impressive manner in which he conducted the public services of the Lord's day, than by the amiable and condescending spirit with which he performed the more private duties of visiting and catechising in the different districts of his parish; duties which, as they were wont to be performed by the Scotch clergy, contributed much more than preaching to the religious instruction of the lower classes of the people.

It was during his residence at Alloa that Mr Fordyce first distinguished himself as an author by the successive publication of the three following sermons. The first, upon the eloquence of the pulpit, was annexed to "the Art of Preaching" by his brother David; the second, upon the methods of promoting edification by public institutions, was preached at the ordination of the Rev. Mr Gibson minister of St Ninian's, a neighbouring parish, in the year 1754, and published, with the charge and notes, in 1755; and the third, upon the delusive and persecuting spirit of popery, was preached the same year before the synod of Stirling and Perth; and being published, came very quickly to a second edition. But the sermon which most strongly arrested the attention, both of the audience before which it was delivered, and of the public to which, in 1760, it was given from the press, was that on the *folly, infamy, and misery of unlawful pleasure*, preached before the General Assembly of the Church of Scotland. The choice of such a subject, on such an occasion, excited the surprise of all his hearers, and tempted the younger part of them to smile at the very reading of the text; but this unseasonable mirth was soon converted into seriousness. The picture exhibited in this sermon is the work of a master; and we have been assured by a friend who heard it preached, that the spirit and elegance of the composition was so seconded by the solemnity and animation with which it was delivered, that it made a very striking impression, not only upon the more respectable part of the audience, but upon minds of noted levity: It raised indeed its writer's fame as a pulpit orator to an unrivalled eminence among his brethren in Scotland.

About this time, and we believe in consequence of this sermon, Mr Fordyce received from the university of Glasgow a diploma, creating him Doctor in Divinity; and if there is yet any thing honourable in academical degrees, prostituted as they have long been by an undistinguishing distribution, the honour could not have been conferred with greater propriety on any man in the church to which he then belonged.

In that church he did not long remain. Soon after the publication of this singular sermon, and his consequent acquisition of academical honours, he accepted of an invitation from a society of Protestant dissenters, who had their place of meeting in Monkwell-street, London, to become colleague and successor to their pastor, who was then old and infirm, and who died, indeed, in the space of a few months. This gave occasion to the Doctor to display his oratory once more both from the pulpit and the press in a sermon on the death of Dr Lawrence. He was now sole pastor to
the

Fordyce. the congregation of Monkwell-street; and preached for many years with great powers of eloquence and fervour of piety, to an audience always crowded and often overflowing.

When a preacher obtains, with or without merit, an uncommon share of popularity, a considerable proportion of his hearers will ever consist of those, who are guided in their choice rather by curiosity and fashion, than by sound judgment. The attachments of such people are as capricious and variable as their minds; and they change their preacher as they change their dress, not from their own taste, for in general they have none; but from the desire of being where others are, of doing what others do, and of admiring what others admire. Dr Fordyce appreciated justly the value of such mens approbation, and knew it eventually by experience; but he was more than compensated for the loss of hearers of this description by the steady adherence of others, whose esteem was most desirable, because it was grounded upon the dictates of a sound understanding.

At last, about Christmas 1782, when his health, which had long been declining, rendered it necessary, in his own opinion, and in the opinion of his physicians, to discontinue his public services, he resigned his charge in Monkwell-street, and retired to a villa in Hampshire, in the neighbourhood of the Earl of Bute, who honoured him with his friendship, and to whose valuable library he had free access. Afterwards he removed to Bath, where having, with Christian patience, suffered much from an asthmatic complaint, to which he had been subject for some years, on the 1st of October 1796 he expired without a groan.

Were we to hazard an opinion of Dr Fordyce's intellectual powers from such a perusal of his works as we must acknowledge to have been hasty, we would say that he was a man of genius rather than of judgment; that his imagination was the predominant faculty of his mind; and that he was better fitted, by an address to the passions, to enforce the practice of virtue, than, by the exertions of his own understanding, to vindicate speculative truth, or to detect the sophistry of error. From this remark, we cannot be suspected of a wish to lessen his character in the public esteem; for his talents, as they appear to us, are surely of more value to a preacher than those which are perhaps better adapted to literary or scientific pursuits. In none of his works indeed do we perceive any evidence either of profound science, or of various erudition; though we doubt not but those works are every thing which their author intended them to be. Of his sermons to young women, which have attracted most general notice, it would be presumptuous in us to give a character; for though we sat down many years ago to read them, we could not get through; and we have never made a second attempt. As far as we can depend upon what we recollect of these far-famed discourses, the censure passed on them by Mrs Wolstoncraft seems to be just. Their author, however, was certainly qualified to excel, and actually did excel as a preacher. We have already men-

tioned with approbation three or four of his occasional sermons; but perhaps the finest specimen of pulpit oratory which ever fell from his pen, is the charge which he delivered at the ordination of his successor in the meeting of Monkwell-street. It is indeed one of the most valuable discourses of the kind that we have seen, and should be read with attention by every clergyman of every denomination, who wishes to discharge his duty with credit to himself and with advantage to his people.

The effect of Dr Fordyce's addresses from the pulpit was much heightened, not only by an action and an elocution, which he studied with care and practised with success; but by the figure of his person, which was peculiarly dignified, and by the expression of his countenance, which was animated at all times, but animated most of all when lighted up by the ardour of his soul in the service of God. By some of his hearers, it was observed that, on many occasions, he seemed not merely to speak, but to look conviction to the heart. His eye, indeed, was particularly bright and penetrating, and he had carefully attended to the effect which an orator may often produce upon an audience by the judicious use of that little, but invaluable organ.

With respect to his theological sentiments, we are assured (A) they were in no extreme, but liberal, rational, and manly. He seems to have been untainted by that rage of innovation, which of late has so completely disfigured the creed, as well religious as political, of the great body of English dissenters. The consequence was, that he lived on terms of friendship with men of very opposite sentiments; with Price a republican and Arian, and with Johnson, who, though he hated a whig and a Presbyterian, respected talents and worth wherever he found them.

We shall conclude this short sketch of Dr Fordyce's life and character with the following list of his works, of which some have been translated into several languages. 1. A Sermon and Charge, at the ordination of the Rev. Mr Gibson Minister of St Ninian's, 1754. 2. Another Ordination Sermon on the Eloquence of the Pulpit, annexed to his brother's "Art of Preaching," 1754. 3. A Sermon on the Spirit of Popery, 1754. 4. A Sermon on the Folly, Infamy, and Misery of Unlawful Pleasure, 1760. 5. A Sermon on the Death of Dr Lawrence, 1760. 6. Sermons to Young Women, 2 vols. 1765. 7. A Sermon on the Character and Conduct of the Female Sex, 1776. 8. Addresses to Young Men, 2 vols. 1777. 9. A Charge at the Ordination of the Rev. James Lindsay, in Monkwell-street, 1783. 10. Addresses to the Deity, 1785. 11. Poems, 1786. 12. A Discourse on Pain, 1791. He also re-published, with an additional character, "The Temple of Virtue, a Dream," written by his brother David.

FORMULA, a theorem or general rule or expression, for resolving certain particular cases of some problem, &c. So $\frac{1}{2}s + \frac{1}{2}d$ is a general formula for the greater of two quantities whose sum is s and difference d ; and $\frac{1}{2}s - \frac{1}{2}d$ is the formula, or general value, for the

(A) By his successor in Monkwell-street, to whose sermon, preached on occasion of the Doctor's death, our readers are indebted for every thing valuable in this short memoir.

Forster. the less quantity. Also $\sqrt{dx - x^2}$ is the formula, or general value of the ordinate to a circle, whose diameter is d , and absciss x .

FORSTER (John Reinhold, LL. D.) professor of natural history in the university of Halle, member of the academy of sciences at Berlin, and of other learned societies, was born at Dirschau, in West Prussia, in the month of October 1729, and was formerly a Protestant clergyman at Dantzick. He had a numerous family, and the emoluments of his office were slender. He therefore quitted Dantzick, and went, first to Russia, and thence to England, in quest of a better settlement than his own country afforded. In the dissenting academy at Warrington he was appointed tutor in the modern languages, with the occasional office of lecturing in various branches of natural history. For the first department he was by no means well qualified; his extraordinary knowledge of languages, ancient and modern, being unaccompanied by a particle of taste; and his use of them being all barbarous, though fluent. As a natural historian, a critic, geographer, and antiquary, he ranked much higher; but unfortunately these were acquisitions of little value in his academical department.

At length he obtained the appointment of naturalist and philosopher (if the word may be so used) to the second voyage of discovery undertaken by Capt. Cook; and from 1772 to 1775 he accompanied that immortal navigator round the world. On his return he resided in London till the improper conduct of himself and his son made it expedient for them both to leave the kingdom. Fortunately he received an invitation to Halle, where, for 18 years, he was a member of the philosophical and medical faculties. Among his works are: An Introduction to Mineralogy, or, An accurate Classification of Fossils and Minerals, &c. London, 1768, 8vo. A Catalogue of the Animals of North America, with short Directions for collecting, preserving, and transporting all kinds of Natural Curiosities, London, 1771, 8vo. Observations made during a Voyage round the World, on Physical Geography, &c. London, 1778. He was the author of a great many productions in English, Latin, or German, and of several papers in the Philosophical Transactions. He translated into English, Bougainville's Voyage round the World, and Kalm's, Boffu's, and Reidel's Travels. He was employed likewise, when in England, in the Critical Review; and he wrote various detached papers on different subjects, which have been inserted in foreign journals and the transactions of learned academies.

He died at Halle on the 16th of December 1798, in the 70th year of his age.

FORSTER (George), the son of the preceding, was born at Dantzick, and accompanied his father to England when he was about twelve years of age. He was entered a student in the academy at Warrington, and soon acquired a very perfect use of the English tongue. He also distinguished himself greatly by his attainments in science and literature in general; adding to an excellent memory, quick parts and a fertile imagination. His temper was mild and amiable; in which he much differed from his father, one of the most quarrelsome and irritable of men; by which disposition, joined to a total want of prudence in common concerns, he lost almost all

the friends his talents had acquired him, and involved himself and family in perpetual difficulties. Forster.

The case was very different with the subject of this memoir; for when Dr Forster was appointed naturalist to Captain Cook, his son, through the interest of the friends whom his good nature had made, was associated with him in his office. The voyage continued during the space of three years; and on their return the two Forsters published jointly a botanical work in Latin, containing the characters of a number of new genera of plants, discovered by them in their circumnavigation. Thus far they acted properly in the service of government for the advancement of science; but in publishing another work their conduct was not proper.

The father had come under an engagement not to publish separately, from the authorized narrative, any account of the voyage; and this engagement he and his son were determined to violate. An account of the voyage, therefore, was published in English and German by George; and the language, which is correct and elegant, was undoubtedly his; but those who knew both him and his father, are satisfied that the matter proceeded from the joint stock of their observations and reflections. Several parts of the work, and particularly the elaborate investigations relative to the languages spoken by the natives of the South Sea Islands, and the speculations concerning their successive migrations, are thought to be strongly impressed with the genius of the elder Forster.

That a work thus surreptitiously ushered into the world was not patronised by those with whom the authors had so ungratefully broken faith, could excite no wonder, even though the publication itself had been otherwise unexceptionable; but this was far from being the case. It abounds with reflections injurious to the government whose servants they had been, and not just to the navigators employed on voyages of discovery. The younger Forster, too, had some time before published a book replete with factious sentiments; and the coldness with which he and his father were both treated in consequence of such conduct, determined them to leave London.

We have already related all that we know of the father, who was recommended to our notice only by his connection with the illustrious Cook; and of the son, there is a short account in the Monthly Magazine, by Charles Pougens, fraught with those impious and seditious reflections which so frequently disgrace a miscellany, which would otherwise be highly valuable. According to this author, George Forster was desirous to settle in France. Avaricious of glory, and an idolator of liberty, Paris was the city most suitable to his taste and character of any in Europe. Notwithstanding this, he was soon constrained to leave it; the interest of his family demanded this sacrifice; for a learned man, who sails round the world, may enrich his memory, but he will not better his fortune. He was accordingly obliged to accept the place of professor of natural history in the university of Cassel. But his factious spirit accompanied him whithersoever he went. It is well known, that the petty princes of Germany have long been in the practice of hiring out their troops to more opulent sovereigns engaged in war. This practice, which we are not disposed to defend, not only scandalized our Cosmopolite, but so irritated

Forster.

ritated his temper and offended his pride, because, forsooth, the Prince of Hesse-Cassel would not by *him* be persuaded to relinquish it, that he did every thing in his power, we are told, to withdraw himself from a situation so unsuitable to a thinking being. Every thing in his power! Did the Prince retain him in the university contrary to his inclination? The university of Cassel must be contemptible indeed, if the prelections of such a man as George Forster were of such consequence to it.

He got away, however; and the senate of Poland having offered him a chair in the university of Wilna, Forster accepted of the invitation. But although this office was very lucrative, and the enlightened patriots of that country did not neglect to procure him all the literary succours of which he stood in need, he could not be long happy in a semi-barbarous nation, in which liberty was suffered to expire under the intrigues of Russia and Prussia.

On this, with wonderful consistency, the man who could not endure the despotism of Hesse, or even the aristocracy of England, accepted of the propositions of that friend to liberty Catharine II.; who, jealous of every species of glory, wished to signalize her reign, by procuring to the Russian nation the honour of undertaking, after the example of England and France, a new voyage of discovery round the world. Unfortunately for the progress of knowledge, the war with the Ottoman Porte occasioned the miscarriage of this useful project.

But Forster could not long remain in obscurity. The different publications with which he occasionally enriched natural history and literature, encreased his reputation. The Elector of Mentz accordingly appointed him president of the university of the same name; and he was discharging the functions of his new office when the French troops took possession of the capital. This philosophical traveller, who had studied society under all the various aspects arising from different degrees of civilization; who had viewed man simple and happy at Otaheite;—an eater of human flesh in New Zealand, corrupted by commerce in England, depraved in France by luxury and atheism, in Brabant by superstition, and in Poland by anarchy;—beheld with wild enthusiasm the dawning of the French revolution, and was the first, says M. Pougens, to promulgate republicanism in Germany.

The *Mayençois*, who had formed themselves into a national convention, sent him to Paris, in order to solicit their *reunion* with the French republic. But, in the course of his mission, the city of Mentz was besieged and retaken by the Prussian troops. This event occasioned the loss of all his property; and what was still more disastrous, that of his numerous manuscripts, which fell into the hands of the Prince of Prussia.

Our biographer, after conducting his hero through these scenes of public life, proceeds to give us a view of his domestic habits and private principles. He tells us, that he formed a connection (whether a marriage or not, the studied ambiguity of his language leaves rather uncertain) with a young woman named *Theresa Hayne*, who, by the illumination of French philosophy, had divested herself of all the prejudices which, we trust, the ladies of this country still consider as their honour, as

they are certainly the guardians of domestic peace. Miss Hayne was indignant at the very *name of duty*. With Eloisa she had taken it into her head that

Forster

Fossil.

Love, free as air, at sight of human ties,
Spreads his light wings, and in a moment dies.

She was frank enough, however, says our author, to acknowledge the errors of her imagination; and from this expression, and his calling her afterwards Forster's wife, we are led to suppose that she was actually married to him. But their union, of whatever kind, was of short duration. Though the lady is said to have been passionately attached to celebrated names, the *name* of George Forster was not sufficient to satisfy her. He soon ceased, we are informed, to *please* her; she therefore transferred her affections to another; and, as was very natural for a woman who was indignant at the name of duty, she proved false to her husband's bed. Forster, however, pretended to be such a friend to the *modern* rights of men and women, that he defended the character of his Theresa against crowds who condemned her conduct. Nay, we are told, that he considered himself, and every other husband who ceases to please, as the *adulterer of nature*. He therefore laboured strenuously to obtain a divorce, to enable Theresa Hayne to espouse the man whom she preferred to himself. Strange, however, to tell, the prejudices even of this Cosmopolite were too strong for his principles. While he was endeavouring to procure the divorce, he made preparations at the same time, by the study of the oriental languages, to undertake a journey to Thibet and Indostan, in order to remove from that part of the world, in which both his heart and his person had experienced so severe a shock. But the chagrin occasioned by his misfortunes, joined to a scorbutic affection, to which he had been long subject, and which he had contracted at sea during the voyage of circumnavigation, abridged his life, and prevented him from realising this double project. He died at Paris, at the age of 39, on the 13th of February 1792.

This is a strange tale; but we trust it will not prove useless. The latter part of it at least shows, that when men divest themselves of the principles of religion, they soon degenerate from the dignity of philosophers to the level of mere sensualists; and that the woman who can, in defiance of decorum and honour, transfer her affections and her person from man to man, ranks no higher in the scale of being than a female brute of more than common sagacity. It shews likewise, that the contempt of our modern sages for those partial attachments which unite individuals in one family, is a mere pretence; that the dictates of nature will be heard; and the laws of nature's God obeyed. George Forster, though he was such a zealous advocate for liberty and equality, as to vindicate the adultery of his wife; yet felt so sensibly the wound which her infidelity inflicted on his honour, that he could not survive it, but perished, in consequence, in the flower of his age.

ROYAL FORT, is one whose line of defence is at least 26 fathoms long.

Star Fort, is a sconce or redoubt, constituted by re-entering and saliant angles, having commonly from five to eight points, and the sides flanking each other.

FOSSIL-MEAL, otherwife called *lac lune*, mineral argaric,

Fossil,
Foulahs.

argaric, and guhr, is, according to M. Fabbroni, a mixed earth, which exhales an argillaceous odour, and throws out a light whitish smoke when sprinkled with water. It is abundant in Tuscany, where it is employed for cleaning plate. It does not effervesce with acids; is infusible in the fire, in which it loses an eighth part of its weight, though it becomes scarcely diminished in bulk; and, according to the analysis made by M. Fabbroni, consists of the following component parts: Siliceous earth 55, magnesia 15, water 14, argil 12, lime 3, iron 1. With this earth, which is found near Casteldelpiano in the territories of Sienna, M. Fabbroni composed bricks, which, either baked or unbaked, floated in water. Hence he infers, that the floating bricks, which Pliny mentions as peculiar to Massilia and Calento, two cities in Spain, must have been made of fossil meal. Bricks made of that substance resist water exceedingly well, and unite perfectly with lime; they are subject to no alteration either by heat or cold; and about a twentieth part of argil may be added with advantage to their composition, without depriving them of the property of floating. M. Fabbroni tried their resistance, and found it very little inferior to that of common bricks; but it is much greater in proportion to their lightness. One of these bricks, seven inches in length, four and a half in breadth, and one inch eight lines in thickness, weighed only $14\frac{7}{8}$ th ounces; whereas a common brick weighed 5 pounds $6\frac{3}{4}$ ths ounces.

Bricks of fossil-meal may be of important benefit in the construction of reverberating furnaces; as they are such bad conductors of heat, that a person may bring one half of them to a red heat, while the other is held in the hand. They may be employed also for buildings that require to be light; for constructing cooking places on board ships; and also floating batteries, the parapets of which, if made of these bricks, would be proof against red hot bullets; and, lastly, for constructing powder magazines.

FOULAHS, or **FOOLAHS**, a people in Africa, inhabiting a country on the confines of the great desert (see **SAHARA** in this *Suppl.*), along the parallel of nine degrees north. They partake much of the negro form and complexion; but have neither the *jetty* colour, *thick* lips, nor *crisped* hair of the negroes. They have also a language distinct from the Mandinga, which is the prevailing one in this quarter. The Foulahs occupy, at least as sovereigns, several provinces or kingdoms, interspersed throughout the tract comprehended between the mountainous border of the country of Sierra Leona on the west, and that of Tombuctoo on the east; as also a large tract on the lower part of the Senegal river; and these provinces are insulated from each other in a very remarkable manner. Their religion is Mahomedanism; but with a great mixture of Paganism, and with less intolerance than is practised by the Moors.

The principal of the Foulah states is that within Sierra Leona; and of which Teemboo is the capital. The next in order appears to be that bordering on the south of the Senegal river, and on the Jaloffs; this is properly named Siratik. Others of less note are Bondon, with Foota-Torra adjacent to it, lying between the rivers Gambia and Falemé; Foola-doo and Brooko along the upper part of the Senegal river; Wassila beyond the upper part of the Niger; and Massina lower down

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on the same river, and joining to Tombuctoo on the west.

The kingdom of the Foulahs, situated between the upper part of the Gambia river and the coast of Sierra Leona, and along the Rio Grande, is governed by a Mahometan sovereign; but the bulk of the people appear to be Pagans. From the circumstances of their long hair, their lips, and comparatively light colour, Major Rennel is decidedly of opinion, that the Foulah's are the Leucæthiops of Ptolemy and Pliny. The former, as he observes, places the Leucæthiops in the situation occupied by the Foulahs; and by the name which he gave them, he evidently meant to describe a people *less* black than the generality of the Ethiopians. Hence it may be gathered that this nation had been traded with, and that some notices respecting it had been communicated to Ptolemy. It may also be remarked, that the navigation of Hanno terminated on this coast; and as this was also the term of Ptolemy's knowledge, it may justly be suspected that this part of the coast was described from Carthaginian materials.

Those who have perused the Journal of Messrs Watt and Winterbottom through the Foulah country in 1794, and recollect how flattering a picture they give of the urbanity and hospitality of the Foulah's, will be gratified on finding that this nation was known and distinguished from the rest of the Ethiopians at a remote period of antiquity.

The contrast between the Moorish and Negro characters is as great as that between the nature of their respective countries, or between their form and complexion. The Moors appear to possess the vices of the Arabs without their virtues; and to avail themselves of an intolerant religion, to oppress strangers: whilst the Negroes, and especially the Mandingas, unable to comprehend a doctrine that substitutes opinion or belief for the social duties, are content to remain in their humble state of ignorance. The hospitality shewn by these good people to Mr Park, a destitute and forlorn stranger, raises them very high in the scale of humanity: and I know of no fitter title, says Mr Rennel, to confer on them than that of the *Hindoos of Africa*; at the same time, by no means intending to degrade the Mahomedans of India by a comparison with the African Moors.—See *Major Rennel's Geographical Illustrations of Mr Park's Journey, and of North Africa at large*, printed for the African Association.

FRANCAIS (**PORT DES**), the name given by Perouse to a bay, or rather harbour, which he undoubtedly discovered on the north-west coast of America. It is situated, according to him, in $58^{\circ} 37'$ N. Lat. and in $139^{\circ} 50'$ W. Long. from Paris. When the two frigates which he commanded approached it, as they were stretching along the coast from south to north, he perceived from his ship a great reef of rocks, behind which the sea was very calm. This reef appeared to be about three or four hundred toises in length from east to west, and to be terminated, at about two cables length, by the point of the continent, leaving a pretty large opening; so that Nature seemed to have made, at the extremity of America, a harbour like that of Toulon, only more vast in her designs and in her means: this new harbour was three or four leagues deep.

Some officers, who had been dispatched in boats to reconnoitre this harbour, gave a report of it extremely favourable;

Foulahs,
français.

Français. favourable; and on the 3d of July 1786, the two frigates entered it, and anchored near its mouth in three fathoms and a half, rocky bottom. The bay, however, was quickly founded, and much better anchoring ground discovered at an island in the middle of it, where the ships might ride in 20 fathoms water with muddy bottom. This ground was taken possession of, an observatory erected on the island, which was only a musket shot from the ships, and a settlement formed for their stay in the harbour. From a report made by one of the officers who had penetrated towards the bottom of the bay, Perouse had conceived the idea of finding perhaps a channel by which he might proceed into the interior of America; but he was disappointed. The bottom of the bay, indeed, according to him, is one of the most extraordinary places in the world. It is a basin of water, of a depth in the middle that could not be fathomed, bordered by peaked mountains of an excessive height, covered with snow, without a blade of grass upon this immense collection of rocks, condemned by Nature to perpetual sterility. "I never (says he) saw a breath of air ruffle the surface of this water; it is never troubled but by the fall of enormous pieces of ice, which continually detach themselves from five different glaciers, and which in falling make a noise that resounds far in the mountains. The air is in this place so very calm, and the silence so profound, that the mere voice of a man may be heard half a league off, as well as the noise of some sea birds which lay their eggs in the cavities of these rocks."

It was at the extremity of this bay that he was in hopes of finding a passage into the interior of America. He imagined that it might terminate in a great river, of which the course might lie between two mountains; and that this river might take its source in the great lakes to the northward of Canada. Two channels were indeed found, stretching, the one to the east, and the other to the west; but both were very soon terminated by immense glaciers.

In Port des Français the variation of the compass is 28° east, and the dip of the needle 74°. The sea rises there seven feet and a half at full and change of the moon, when it is high water at one o'clock. The sea breezes, or perhaps other causes, act so powerfully upon the current of the channel, that M. Perouse saw the flood come in there like the most rapid river; while, in other circumstances, at the same period of the moon, it may be stemmed by a boat. In this channel he lost two shallops and twenty men. In his different excursions, he found the high water mark to be about 15 feet above the surface of the sea. These tides are probably incident to the bad season. When the winds blow with violence from the southward, the channel must be impracticable, and at all times the currents render the entrance difficult; the going out of it also requires a combination of circumstances, which may retard the departure of a vessel many weeks; there is no getting under way but at the top of high water; the breeze from the west to the north-west does not often rise till toward eleven o'clock, which does not permit the taking

Français. advantage of the morning tide; finally, the easterly winds, which are contrary, appeared to him to be more frequent than those from the west, and the vast height of the surrounding mountains never permits the land breezes, or those from the north, to penetrate into the road.

As this port possesses great advantages, M. Perouse thought it a duty incumbent on him to make its inconveniences also known. It seemed to him that this anchorage is not convenient for those ships which are sent out at a venture for trafficking in skins; such ships ought to anchor in a great many bays, and always make the shortest stay possible in any of them; because the Indians have always disposed of their whole stock in the first week, and all lost time is prejudicial to the interests of the owners: but a nation which should form the project of establishing factories similar to those of the English in Hudson's Bay, could not make choice of a place more proper for such a settlement. A simple battery of four heavy cannon, placed upon the point of the continent, would be fully adequate to the defence of so narrow an entrance, which is also made so difficult by the currents. This battery could not be turned or taken by land, because the sea always breaks with such violence upon the coast, that to disembark is impossible. The fort, the magazines, and all the settlements for commerce, should be raised upon Cenotaph Island (A), the circumference of which is nearly a league: it is capable of being cultivated, and there is plenty of wood and water. The ships not having their cargo to seek, but being certain of having it collected to a single point, would not be exposed to any delay: some buoys, placed for the internal navigation of the bay, would make it extremely safe and easy. The settlement would form pilots, who, better versed than we are in the set and strength of the current at particular times of tide, would ensure the entrance and departure of the ships. Finally, continues the author, our traffic for otters skins has been so very considerable, that I may fairly presume there could not, in any part of America, be a greater quantity of them collected.

The climate of this coast seemed to Perouse much milder than that of Hudson's Bay in the same latitude. Pines were measured of six feet diameter, and 140 high; while those of the same species at Prince of Wales's Fort and Fort York, are of a dimension scarce sufficient for studding sail-booms. Vegetation is also very vigorous during three or four months of the year; and our author thinks, that Russian corn, as well as many common plants, might thrive exceedingly at Port des Français, where was found great abundance of celery, lupine, the wild pea, yarrow, and andive. Among these pot herbs were seen almost all those of the meadows and mountains of France; such as the angelica, the butter cup, the violet, and many species of grass proper for fodder. The woods abound in gooseberries, raspberries, and strawberries; clusters of elder trees, the dwarf willow, different species of briar which grow in the shade, the gum poplar tree, the poplar, the fallow, the horn-beam; and, finally, superb pines, fit for the masts

(A) This name was given to the island in the bay from the monument erected on it to the memory of their unfortunate companions.

Français. masts of our largest ships. Not any of the vegetable productions of this country are unknown in Europe. M. de Martinière, in his different excursions, met with only three plants which he thought new; and it is well known, that a botanist might do the same in the vicinity of Paris.

The rivers were filled with trout and salmon; and as the Indians sold these fish to the French in greater quantities than they could consume, they had very little fishing in the bay, and that only with the line. They caught some ling, a single thornback, some plaice, *stetans* or *saitans*, of which some were more than 100 pounds in weight (B), and a fish resembling the whiting, but a little larger, which abounds on the coast of Provence, where it is known by the name of *poor priest*. Perouse calls these fish *capelans*. In the woods they met with bears, martens, and squirrels; but they saw no great variety of birds, though the individuals were very numerous.

“If the animal and vegetable productions of this country resemble those of a great many others, its appearance (says our author) can be compared to nothing. The views which it presents are more frightful than those of the Alps and the Pyrenees; but at the same time so picturesque, that they would deserve the visits of the curious, were they not at the extremity of the world. The primitive mountains of granite or schistus, perpetually covered with snow, upon which are neither trees nor plants, have their foundation in the sea, and form upon the shore a kind of quay; their slope is so rapid, that after the first two or three hundred toises, the wild goats cannot climb them; and all the gullies which separate them are immense glaciers, of which the tops cannot be discerned, while the base is washed by the sea. At a cable’s length from the land there is no bottom at less than 160 fathoms. The sides of the harbour are formed by secondary mountains, the elevation of which does not exceed from 800 to 900 toises; they are covered with pines, and overspread with verdure, and the snow is only seen on their summits: they appeared to be entirely formed of schistus, which is in the commencement of a state of decomposition; they are extremely difficult to climb, but not altogether inaccessible.

“Nature assigns inhabitants to so frightful a country, who as widely differ from the people of civilized countries as the scene which has just been described differs from our cultivated plains; as rude and barbarous as their soil is rocky and barren, they inhabit this land only to destroy its population: at war with all the animals, they despise the vegetable substances that grow around them. I have seen (says our author) women and children eat some raspberries and strawberries; but these are undoubtedly viands far too insipid for men, who live upon the earth like vultures in the air, or wolves and tigers in the forests.

“Their arts are somewhat advanced, and in this respect civilization has made considerable progress; but that which softens their ferocity, and polishes their manners, is yet in its infancy. The mode of life they pursue excluding all kind of subordination, they are

continually agitated by fear or revenge; prone to anger, and easily irritated, they are continually attacking each other dagger in hand. Exposed in the winter to perish for want, because the chase cannot be successful, they live during the summer in the greatest abundance, as they can catch in less than an hour a sufficient quantity of fish for the support of their family; they remain idle during the rest of the day, which they pass at play, to which they are as much addicted as some of the inhabitants in our great cities. This gaming is the great source of their quarrels. If to all these destructive vices they should unfortunately add a knowledge of the use of any inebriating liquor, M. Perouse does not hesitate to pronounce, that this colony would be entirely annihilated.”

Like all other savages, they are incorrigible thieves; and when they assumed a mild and placid appearance, the Frenchmen were sure that they had stolen something. Iron, of which they appeared to know the use, and of course the value, most excited their cupidity; and when our navigators were engaged in caressing a child, the father was sure to seize the opportunity of taking up, and concealing under his skin-garment, every thing of that metal which lay within his reach, and was not too heavy to be carried off.

M. Rollin, surgeon major of one of the frigates, thus describes these people. “They have very little similarity to the Californians; they are taller, stouter, of a more agreeable figure, and greater vivacity of expression: they are also much their superiors in courage and sense. They have rather a low forehead, but more open than that of the Southern Americans; their eyes are black and very animated; their eyebrows much fuller; their nose of the usual size, and well formed, except being a little widened at the extremity; their lips thinner; their mouth moderately large; their teeth fine and very even; their chin and ears very regular.

“The women also have an equal advantage over those of the preceding tribes; they have much more mildness in their features and grace in their limbs.— Their countenance would be even very agreeable, if, in order to set it off, they did not make use of a strange custom of wearing in the lower lip an elliptical piece of wood, lightly grooved on its circumference and both its sides, and which is commonly half an inch thick, two in diameter, and three in length.

“This singular ornament, besides being a great deformity, is the cause of a very troublesome as well as disgusting involuntary flow of saliva. This appendage is peculiar to the women; and female children are made to undergo the preparatory operations from the time of their birth. For this purpose, the lower lip is pierced with a kind of pin of copper or gold, which is either left in the opening, or its place supplied with a ring of the same material, till the period of puberty. The aperture is then gradually enlarged, by substituting first a small piece of wood of the form mentioned above, then a larger one; and so on, increasing its size by degrees till it reaches the dimensions just stated.

“This extraordinary custom shews the great power of dilatation in the lip, and may encourage medical practitioners

(B) This is a flat fish, longer and not so square as the turbot. Its back is covered with small scales; and those which are taken in Europe are much less than the *stetans* of Port des Français

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||
Friction.

tioners in their attempts to remedy deformities of this part by the use of the knife.

"The general colour of these people is olive, a fainter tinge of which is apparent in their nails, which they suffer to grow very long; the hue of the skin, however, varies in different individuals, and in various parts of the same individual, according to their exposure to the action of the air and sun.

"Their hair is, in general, neither so coarse nor black as that of the South Americans. Chestnut coloured hair is by no means unfrequent among them. Their beard is also fuller, and their armpits and parts of sex better provided with hair.

"The perfect evenness of their teeth led me at first to suspect that it was the effect of art; but after an attentive and minute examination, I could perceive no wearing away of the enamel, and I saw that this regularity is natural. They tattoo and paint their face and body, and bore their ears and the cartilage of their nose.

"Some writers have imagined, that the custom of painting the face and body, so generally adopted by the Africans, Americans, and West Indians, is only intended as a preservative against noxious insects. I think, however, that I am warranted in asserting its sole end to be ornament. I found it to prevail among the inhabitants of Easter Island and the natives of *Port des Français*, without observing among them either venomous insects or reptiles. Besides, I remarked that they wore paint only when they paid us a visit; for they made no use of it when in their own houses."

M. Perouse himself speaks not so favourably of the women as M. Rollin. "They are (he says) the most disgusting of any on the earth, covered with stinking skins, which are frequently untanned; and yet they failed not to excite desires in some persons, in fact of no small consequence: they at first started many difficulties, giving assurances by their gestures that they ran the risk of their lives; but being overcome by presents, they had no objection to the sun being a witness, and absolutely refused to retire into the wood." There can be no doubt that this planet is the god of these people, since they frequently addressed themselves to it in their prayers; but our voyagers saw neither temple nor priest, nor the least trace of public worship at stated times. They burn their dead.

FREGATES FRANÇAISE *Basse de*, the name given by La Perouse to a dangerous reef of sunken rocks which he discovered in the Pacific ocean. On the north-west extremity of this reef they perceived an islet or split rock from 20 to 25 fathoms in height and about 50 toises in diameter. From this islet the reef extends more than four leagues to the south-east; and upon the extremity of the point in that direction, the frigates had almost struck before the breakers were observed. This was during a fine clear night and smooth sea. With great propriety, the Commodore returned in the morning to ascertain the geographical situation of this unknown rock; and he estimated the islet to be in 23° 45' N. Lat. and 168° 10' W. Long. from Paris.

FRICITION, in mechanics, is a subject of great importance both to the practical engineer and to the speculative philosopher. It is therefore our duty to correct, in this Supplement, the mistakes into which we fell when treating of that subject in the *Encyclopædia*. What we have there taught of friction (see МЕЧНА-

FRICITION, Sect. II. § 8.) is taken from Ferguson; but it has been shewn by Mr Vince, that the experiments from which his conclusions were drawn were not properly instituted. That eminent mathematician and philosopher therefore entered upon the investigation of the subject anew, and endeavoured, by a set of experiments, to determine the following questions:

1. Whether friction be a uniformly retarding force?
2. The quantity of friction?
3. Whether the friction varies in proportion to the pressure or weight?
4. Whether the friction be the same on whichever of its surfaces a body moves?

1. With respect to the first of these questions, the author truly observes, that if friction be a uniform force, the difference between it and the given force of the moving power employed to overcome it must also be uniform; and that therefore the moving power, if it be a body descending by its own weight, must descend with a uniformly accelerated velocity, just as when there was no friction. The spaces described from the beginning of the motion will indeed be diminished in any given time on account of the friction; but still they must be to each other as the squares of the times employed. See DYNAMICS in this Supplement.

2. A plane was therefore adjusted parallel to the horizon, at the extremity of which was placed a pulley, which could be elevated or depressed, in order to render the string which connected the body and the moving force parallel to the plane. A scale accurately divided was placed by the side of the pulley perpendicular to the horizon, by the side of which the moving force descended; upon the scale was placed a moveable stage, which could be adjusted to the space through which the moving force descended in any given time; which time was measured by a well-regulated pendulum clock vibrating seconds. Every thing being thus prepared, the following experiments were made to ascertain the law of friction.

3. *Exp. 1.* A body was placed upon the horizontal plane, and a moving force applied, which, from repeated trials, was found to descend $52\frac{1}{2}$ inches in 4"; for by the beat of the clock, and the found of the moving force when it arrived at the stage, the space could be very accurately adjusted to the time: The stage was then removed to that point to which the moving force would descend in 3", upon supposition that the spaces described by the moving power were as the squares of the times; and the space was found to agree very accurately with the time: the stage was then removed to that point to which the moving force ought to descend in 2", upon the same supposition, and the descent was found to agree exactly with the time: lastly, the stage was adjusted to that point to which the moving force ought to descend in 1", upon the same supposition, and the space was observed to agree with the time. Now, in order to find whether a difference in the time of descent could be observed by removing the stage a little above and below the positions which corresponded to the above times, the experiment was tried, and the descent was always found too soon in the former, and too late in the latter case; by which the author was assured, that the spaces first mentioned corresponded exactly to the times. And, for the greater certainty, each descent was repeated eight or ten times; and

Friction. and every caution used in this experiment was also made use of in all the following.

Exp. 2. A second body was laid upon the horizontal plane, and a moving force applied which descended 4.1 $\frac{1}{4}$ inches in 3"; the stage was then adjusted to the space corresponding to 2", upon supposition that the spaces descended through were as the squares of the times, and it was found to agree accurately with the time; the stage was then adjusted to the space corresponding to 1", upon the same supposition, and it was found to agree with the time.

Exp. 3. A third body was laid upon the horizontal plane, and a moving force applied, which descended 59 $\frac{5}{8}$ inches in 4"; the stage was then adjusted to the space corresponding to 3", upon supposition that the spaces descended through were as the squares of the times, and it was found to agree with the time; the stage was then adjusted to the space corresponding to 2", upon the same supposition, and it was found to agree with the time; the stage was then adjusted to the space corresponding to 1", and was found to agree with the time.

Exp. 4. A fourth body was then taken and laid upon the horizontal plane, and a moving force applied, which descended 55 inches in 4"; the stage was then adjusted to the space through which it ought to descend in 3", upon supposition that the spaces descended through were as the squares of the times, and it was found to agree with the time; the stage was then adjusted to the space corresponding to 2", upon the same supposition, and was found to agree with the time; lastly, the stage was adjusted to the space corresponding to 1", and it was found to agree exactly with the time.

Besides these experiments, a great number of others were made with hard bodies, or those whose parts so firmly cohered as not to be moved *inter se* by the friction; and, in each experiment, bodies of very different degrees of friction were chosen, and the results all agreed with those related above; we may therefore conclude, that the *friction of hard bodies in motion is a uniformly retarding force.*

But to determine whether the same was true for bodies when covered with cloth, woollen, &c. experiments were made in order to ascertain it; when it was found, in all cases, that the retarding force increased with the velocity; but, upon covering bodies with paper, the consequences were found to agree with those related above.

4. Having proved that the retarding force of all hard bodies arising from friction is uniform, the quantity of friction, considered as equivalent to a weight without inertia drawing the body on the horizontal plane backwards, or acting contrary to the moving force, may be immediately deduced from the foregoing experiments. For let M = the moving force expressed by its weight; F = the friction; W = the weight of the body upon the horizontal plane; S = the space through which the moving force descended in the time t expressed in seconds; r = 16 $\frac{1}{2}$ feet; then the whole accelerative

force (the force of gravity being unity) will be $\frac{M - F}{M + W}$;

hence, by the laws of uniformly accelerated motions, $\frac{M - F}{M + W} \times r t^2 = S$, consequently $F = M - \frac{M \times W \times S}{r t^2}$.

To exemplify this, let us take the case of the last ex-

periment, where M = 7, W = 25 $\frac{1}{2}$, S = 4 $\frac{1}{2}$ feet, Friction

t = 4"; hence $F = 7 - \frac{32\frac{1}{2} \times 4\frac{1}{2}}{16\frac{1}{2} \times 16} = 6.417$; con-

sequently the friction was to the weight of the rubbing body as 6.4167 to 25.75. And the great accuracy of determining the friction by this method is manifest from hence, that if an error of one inch had been made in the descent (and experiments carefully made may always determine the space to a much greater exactness), it would not have affected the conclusion $\frac{1}{800}$ th part of the whole.

5. We come, in the next place, to determine whether friction, *ceteris paribus*, varies in proportion to the weight or pressure. Now if the whole quantity of the friction of a body, measured by a weight without inertia equivalent to the friction drawing the body backwards, increases in proportion to its weight, it is manifest that the retardation of the velocity of the body arising from the friction will not be altered; for the retardation varies as $\frac{\text{Quantity of friction}}{\text{Quantity of matter}}$; hence, if a

body be put in motion upon the horizontal plane by any moving force, if both the weight of the body and the moving force be increased in the same ratio, the acceleration arising from that moving force will remain the same, because the accelerative force varies as the moving force divided by the whole quantity of matter, and both are increased in the same ratio; and if the quantity of friction increases also as the weight, then the retardation arising from the friction will, from what has been said, remain the same, and therefore the whole acceleration of the body will not be altered; consequently the body ought, upon this supposition, still to describe the same space in the same time. Hence, by observing the spaces described in the same time, when both the body and the moving force are increased in the same ratio, we may determine whether the friction increases in proportion to the weight. The following experiments were therefore made in order to ascertain this matter:

Exp. 1. A body weighing 10 oz. by a moving force of 4 oz. described in 2" a space of 51 inches; by loading the body with 10 oz. and the moving force with 4 oz. it described 56 inches in 2"; and by loading the body again with 10 oz. and the moving force with 4 oz. it described 63 inches in 2".

Exp. 2. A body, whose weight was 16 oz. by a moving force of 5 oz. described a space of 49 inches in 3"; and by loading the body with 64 oz. and the moving force with 20 oz. the space described in the same time was 64 inches.

Exp. 3. A body weighing 6 oz. by a moving force of 2 $\frac{1}{2}$ oz. described 28 inches in 2"; and by loading the body with 24 oz. and the moving force with 10 oz. the space described in the same time was 54 inches.

Exp. 4. A body weighing 8 oz. by a moving force of 4 oz. described 33 $\frac{1}{2}$ inches in 2"; and by loading the body with 8 oz. and the moving force with 4 oz. the space described in the same time was 47 inches.

Exp. 5. A body whose weight was 9 oz. by a moving force of 4 $\frac{1}{2}$ oz. described 48 inches in 2"; and by loading the body with 9 oz. and the moving force with 4 $\frac{1}{2}$ oz. the space described in the same time was 60 inches.

Exp. 6. A body weighing 10 oz. by a moving force of

Friction. 3 oz. described 20 inches in 2"; by loading the body with 50 oz. and the moving force with 3 oz. the space described in the same time was 31 inches; and by loading the body again with 30 oz. and the moving force with 9 oz. the space described was 34 inches in 2".

From these experiments, and many others which it is not necessary here to relate, it appears, that the space described is always increased by increasing the weight of the body and the accelerative force in the same ratio; and as the acceleration arising from the moving force continued the same, it is manifest, that the retardation arising from the friction must have been diminished, for the whole accelerative force must have been increased on account of the increase of the space described in the same time; and hence (as the retardation from

friction varies as $\frac{\text{Quantity of friction}}{\text{Quantity of matter}}$) *the quantity of friction increases in a less ratio than the quantity of matter or weight of the body.*

6. We come now to the last thing which it was proposed to determine, that is, whether the friction varies by varying the surface on which the body moves. Let us call two of the surfaces A and a, the former being the greater, and the latter the less. Now the weight on every given part of a is as much greater than the weight on an equal part of A, as A is greater than a; if therefore the friction was in proportion to the weight, *ceteris paribus*, it is manifest, that the friction on a would be equal to the friction on A, the whole friction being, upon such a supposition, as the weight on any given part of each surface multiplied into the number of such parts or into the whole area, which products, from the proportion above, are equal. But from the last experiments it has been proved, that the friction on any given surface increases in a less ratio than the weight; consequently the friction on any given part of a has a less ratio to the friction on an equal part of A than A has to a, and hence the friction on a is less than the friction on A, that is, the smallest surface has always the least friction.

As this conclusion is contrary to the generally received opinion, Mr Vince thought it proper to confirm it by a set of experiments made with different bodies of exactly the same degree of roughness on their two surfaces.

Exp. 1. A body was taken whose flat surface was to its edge as 22 : 9, and with the same moving force the body described on its flat side 33½ inches in 2", and on its edge 47 inches in the same time.

Exp. 2. A second body was taken whose flat surface was to its edge as 32 : 3, and with the same moving force it described on its flat side 32 inches in 2", and on its edge it described 37½ inches in the same time.

Exp. 3. He took another body and covered one of its surfaces, whose length was 9 inches, with a fine rough paper, and by applying a moving force, it described 25 inches in 2"; he then took off some paper from the middle, leaving only ⅓ths of an inch at the two ends, and with the same moving force it described 40 inches in the same time.

Exp. 4. Another body was taken which had one of its surfaces, whose length was 9 inches, covered with a fine rough paper, and by applying a moving force it described 42 inches in 2"; some of the paper was then taken off from the middle, leaving only 1⅓ inches at

the two ends, and with the same moving force it described 54 inches in 2"; he then took off more paper, leaving only ¼ of an inch at the two ends, and the body then described, by the same moving force, 60 inches in the same time.

In the two last experiments the paper which was taken off the surface was laid on the body, that its weight might not be altered.

Exp. 5. A body was taken whose flat surface was to its edge as 30 : 17; the flat side was laid upon the horizontal plane, a moving force was applied, and the stage was fixed in order to stop the moving force, in consequence of which the body would then go on with the velocity acquired until the friction had destroyed all its motion; when it appeared from a mean of 12 trials that the body moved, after its acceleration ceased, 5⅓ inches before it stopped. The edge was then applied, and the moving force descended through the same space; and it was found, from a mean of the same number of trials, that the space described was 7⅓ inches before the body lost all its motion, after it ceased to be accelerated.

Exp. 6. Another body was then taken whose flat surface was to its edge as 60 : 19, and by proceeding as before, on the flat surface it described, at a mean of 12 trials, 5⅓ inches, and on the edge 6⅓ inches, before it stopped, after the acceleration ceased.

Exp. 7. Another body was taken whose flat surface was to its edge as 26 : 3, and the spaces described on these two surfaces, after the acceleration ended, were, at a mean of ten trials, 4⅓ and 7⅓ inches respectively.

From all these different experiments it appears, that the smallest surface had always the least friction, which agrees with the consequence deduced from the consideration that the friction does not increase in so great a ratio as the weight; we may therefore conclude, that *the friction of a body does not continue the same when it has different surfaces applied to the plane on which it moves, but that the smallest surface will have the least friction.*

To the experiments instituted by Mr Ferguson and others, from which conclusions have been drawn so different from these, our author makes the following objections: It was their object to find what moving force would just put a body at rest in motion; and having, as they thought, found it, they thence concluded, that the accelerative force was then equal to the friction. But it is manifest, as Mr Vince observes, that any force which will put a body in motion must be greater than the force which opposes its motion, otherwise it could not overcome it; and hence, if there were no other objection than this, it is evident, that the friction could not be very accurately obtained: but there is another objection which totally destroys the experiment so far as it tends to shew the quantity of friction, which is the strong cohesion of the body to the plane when it lies at rest; and this is confirmed by the following experiments. 1st, A body of 12¼ oz. was laid upon an horizontal plane, and then loaded with a weight of 8 lb. and such a moving force was applied as would, when the body was just put in motion, continue that motion without any acceleration; in which case the friction must be just equal to the accelerative force. The body was then stopped, when it appeared that the same moving force which had kept the body in motion before,

Friction, Frigorific. fore, would not put it in motion, and it was found necessary to take off $4\frac{1}{2}$ oz. from the body before the same moving force would put it in motion; it appears therefore, that this body, when laid upon the plane, at rest, acquired a very strong cohesion to it. 2dly, A body whose weight was 16 oz. was laid at rest upon the horizontal plane, and it was found that a moving force of 6 oz. would just put it in motion; but that a moving force of 4 oz. would, when it was just put in motion, continue that motion without any acceleration, and therefore the accelerative force must then have been equal to the friction, and not when the moving force of 6 oz. was applied.

From these experiments, therefore, it appears how very considerable the cohesion was in proportion to the friction when the body was in motion; it being, in the latter case, almost $\frac{3}{4}$ d, and in the former it was found to be very nearly equal to the whole friction. All the conclusions therefore deduced from the experiments, which have been instituted to determine the friction from the force necessary to put a body in motion, have manifestly been totally false; as such experiments only shew the resistance which arises from the cohesion and friction conjointly.

Our author concludes this part of his subject with the following remark upon n^o 5: "It appears from all the experiments (says he) which I have made, that the proportion of the increase of the friction to the increase of the weight was different in all the different bodies which were made use of; no general rule therefore can be established to determine this for all bodies, and the experiments which I have hitherto made have not been sufficient to determine it for the same body."

He then proceeds to establish a theory upon the principles which he has deduced from his experiments. That theory is comprehended in five propositions, of which the object of the first is "to find the time of descent, and the number of revolutions made by a cylinder rolling down an inclined plane in consequence of its friction.

II. "To determine the space through which a body, projected on an horizontal plane with a given velocity, will move before it stops, or before its motion becomes uniform.

III. "To find the centre of friction.

IV. "To determine, from the given velocity with which a body begins to revolve about the centre of its base, the number of revolutions which that body will make before all its motion be destroyed.

V. "To find the nature of the curve described by any point of a body affected by friction when it descends down any inclined plane."

To give the solutions of these problems, with the collaries deduced from them, would swell this article to very little purpose; for they would be unintelligible to the mere mechanic, and the mathematician will either solve them for himself, or have recourse to the original memoir, where he will find solutions at once elegant and perspicuous.

FRIGORIFIC MIXTURES, are those which experience has taught philosophers to employ for the pur-

pose of producing artificial cold. Some of these mixtures are enumerated under the title COLD (*Encycl.*), and a much more accurate list of them is given, together with the principle upon which they produce their effect, in the article CHEMISTRY, n^o 282. (*Suppl.*). There is one mixture, however, not mentioned in that list, which was employed by Seguin, and seems, on many accounts, to be the most eligible that has yet been proposed. Considering the muriats (see CHEMISTRY-Index, *Suppl.*) as a class of salts best suited for the purpose, he gave the decided preference to muriat of lime in crystals; and his method was to mix the crystals, previously pulverised, with an equal weight of uncompressed snow.

By means of this mixture Mr W. H. Pepys junior, of the London Philosophical Society, with the assistance of some friends, froze, on the 8th of February 1799, 56 lbs. averdupoise of mercury into a solid mass. The mercury was put into a strong bladder and well secured at the mouth, the temperature of the laboratory at the time being $+ 33^{\circ}$. A mixture consisting of muriat of lime 2 lb. at $+ 33^{\circ}$, and the same weight of snow at $+ 32^{\circ}$ gave $- 42^{\circ}$ (A). The mercury was put as gently as possible into this mixture (to prevent a rupture of the bladder), by means of a cloth held at the four corners. When the cold mixture had robbed the mercury of so much of its heat as to have its own temperature thereby raised from $- 42^{\circ}$ to $+ 5$, another mixture, the same in every respect as the last, was made, which gave, on trial with the thermometer, $- 43^{\circ}$. The mercury was now received into the cloth, and put gently into this new mixture, where it was left to be cooled still lower than before.

In the mean time five pounds of muriat of lime, in a large pail made of tinned iron, and japanned inside and outside, was placed in a cooling mixture in an earthenware pan. The mixture in the pan, which consisted of 4 lb. of muriat of lime and a like quantity of snow, of the same temperature as the former, in one hour reduced the 5 lb. of muriat in the pail to $- 15^{\circ}$. The mixture was then emptied out of the earthen pan, and four large corks, at proper distances, placed on its bottom, to serve as rests for the japanned pail which was now put into the pan. The corks answered the purpose of insulating the inner vessel, while the exterior one kept off the surrounding atmosphere, and preserved the air between the two at a low temperature.

To the 5 lb. of muriat of lime which had been cooled, as already noticed, to $- 15^{\circ}$, and which still remained in the metallic vessel, was now added snow, uncompressed and free from moisture, at the usual temperature of $+ 32^{\circ}$. In less than three minutes the mixture gave a temperature of $- 62^{\circ}$: a degree of cold which perhaps was never before produced in this country, being 94° below the freezing point of water.

The mercury, which, by immersion in the second cooling mixture to which it was exposed, was by this time reduced to $- 30^{\circ}$, was now, by the means employed before, cautiously put into the last made mixture of the temperature of $- 62^{\circ}$. A hoop with network fastened to its upper edge, and of such a breadth in the

rim:

(A) The thermometer made use of in this experiment was filled with tinged alcohol, and accurately divided according to Fahrenheit's scale.

Frigorific. *fin* that the net-work, when loaded with the bladder of mercury, could not reach its lower edge, was at the bottom of the mixture, to prevent the bladder from coming in contact with the vessel; by which means the mercury was suspended in the middle of the mixture. As soon as the bladder was safely deposited on the net-work, the vessels were carefully covered over with a cloth, to impede the passage of heat from the surrounding atmosphere into the freezing materials. The condensation of moisture from the atmosphere by the agency of so low a temperature was greater than could have been expected: it floated like steam over the vessels, and, but for the interposed covering, would have given the mixture more temperature than was desirable.

After one hour and forty minutes they found, by means of a searcher introduced for the purpose, that the mercury was solid and fixed. The temperature of the mixture at this time was — 46, that is, 16° higher than when the mercury was put into it.

Our young philosophers having neglected to sling the hoop and net-work in such a manner as might have enabled them to lift it out of the mixture at once, with the bladder and its contents, were obliged to turn out the whole contents of the pail into a large evaporating capsule made of iron. This was not effected without the mercury striking against its bottom and being fractured, though it received a considerable increase of temperature from the capsule. The fracture was similar to that of zinc, but with parts more cubical. The larger pieces were kept for some minutes before fusion took place, while others were twisted and bent into various forms, to the no small gratification and surprise of those who never witnessed or expected to see such an effect produced on so fusible a metal.

In experiments of the kind here described, all the exterior vessels should be of earthen-ware or wood, which being bad conductors of heat, prevent the ingredients from receiving heat from the atmosphere and surrounding objects with the same facility that they would through metals; and, for a similar reason, the interior vessels are best of metal, that they may allow the heat to pass more readily from the substance to be cooled into the frigorific mixture employed for that purpose.

Muriat of lime is certainly the most powerful, and at the same time the most economical substance that can be employed for producing artificial cold; for its first cost is a mere trifle, being a residuum from many chemical processes, as the distillation of pure ammonia, &c. and often thrown away: besides, it may be repeatedly used for similar experiments, nothing being necessary for this purpose but filtration and evaporation to bring it to its first state. The evaporation should be carried on till the solution becomes as thick as a strong syrup, and upon cooling the whole will be crystallised: it must then be powdered, put up in dry bottles, well corked, and covered with bladder or cement to prevent liquefaction; which otherwise would soon take place, owing to the great affinity the muriat has for moisture.

The powerful effects produced by the frigorific mixture of muriat of lime and snow, present a wide field for experiments to determine the possibility of fixing some of the gases by intense cold. And we are happy to be informed by Mr Pepys, that, as soon as an

opportunity offers, he and his friends mean to make some experiments with that view, and to communicate the result of them to the editor of the valuable miscellany * from which we have taken this account of his experiment on mercury.

FRIO, a small island on the coast of the Brazils, situated in 32° 2' south lat. and 41° 31' 45" west lon. The land of Frio is high, with a hollow in the middle, which gives it, at a distance, the resemblance of two separate islands. The passage between the island and the continent is about a mile broad, and seemed to Sir Erasmus Gower to be clear from shoals.

FROST, as is well known in Scotland, is particularly destructive to the blossom of fruit trees; and the following method of securing such trees from being damaged by early frosts may be acceptable to many of our readers. A rope is to be interwoven among the branches of the tree, and one end of it brought down so as to be immersed in a bucket of water. The rope, it is said, will act as a conductor, and convey the effects of the frost from the tree to the water. This idea is not new; for the following passage may be found in Colerus: "If you dig a trench around the root of a tree, and fill it with water, or keep the roots moist till it has bloomed, it will not be injured by the frost. Or, in spring, suspend a vessel filled with water from the tree. If you wish to preserve the bloom from being hurt by the frost, place a vessel of water below it, and the frost will fall into it." *Philosophical Magazine*, n° 11.

FUEL, whatever is proper to burn, or make a fire; either for warming a room or dressing victuals. The fuel most generally used in Great Britain is pit-coal, which is a very expensive article; and that expence is greatly increased by the waste of coal occasioned by the injudicious manner in which fires in open chimneys are commonly managed. The enormous waste of fuel in London, for instance, may be estimated by the vast dark cloud which continually hangs over that great metropolis, and frequently overshadows the whole country far and wide; for this dense cloud is certainly composed almost entirely of unconsumed coal, which has escaped by the chimneys, and continues to sail about in the air, till, having lost the heat which gave it volatility, it falls in a dry shower of extremely fine black dust to the ground, obscuring the atmosphere in its descent, and frequently changing the brightest day into more than Egyptian darkness.

"I never (says Court Rumford) view from a distance, as I come into town, this black cloud which hangs over London, without wishing to be able to compute the immense number of chaldrons of coals of which it is composed; for could this be ascertained, I am persuaded so striking a fact would awaken the curiosity, and excite the astonishment of all ranks of the inhabitants; and perhaps turn their minds to an object of economy to which they have hitherto paid little attention."

The object to which the benevolent author more particularly wishes to direct the public attention, is the lighting of a coal fire, in which more wood should be employed than is commonly used, and fewer coals; and as soon as the fire burns bright, and the coals are well lighted, and not before, more coals should be added to increase the fire to its proper size.

Kindling balls, composed of equal parts of coal, — charcoal, — and clay, the two former reduced to a fine powder,

F i o
||
Fuel

* The Phi-
losophical
Magazine.

Fuel,
Fulling.

powder, well mixed and kneaded together, with the clay moistened with water, and then formed into balls of the size of hens eggs, and thoroughly dried, might be used with great advantage instead of wood for kindling fires. These kindling balls may be made so inflammable as to take fire in an instant and with the smallest spark, by dipping them in a strong solution of nitre, and then drying them again; and they would neither be expensive nor liable to be spoiled by long keeping. Perhaps a quantity of pure charcoal, reduced to a very fine powder, and mixed with the solution of nitre in which they are dipped, would render them still more inflammable.

The Count thinks that the fires which are made in the open chimneys of elegant apartments might be greatly improved by preparing the fuel; for nothing (says he) was ever more dirty, inelegant, and disgusting, than a common coal fire.

Fire balls, of the size of goose eggs, composed of coal and charcoal in powder, mixed up with a due proportion of wet clay, and well dried, would make a much more cleanly, and in all respects a pleasanter fire, than can be made with crude coals; and, he believes, would not be more expensive fuel. In Flanders, and in several parts of Germany, and particularly in the duchies of Juliers and Bergen, where coals are used as fuel, the coals are always prepared before they are used, by pounding them to a powder, and mixing them up with an equal weight of clay, and a sufficient quantity of water to form the whole into a mass, which is kneaded together and formed into cakes; which cakes are afterwards well dried and kept in a dry place for use. And it has been found, by long experience, that the expence attending this preparation is amply repaid by the improvement of the fuel. The coals, thus mixed with clay, not only burn longer, but give much more heat than when they are burnt in their crude state.

It will doubtless appear extraordinary to those who have not considered the subject with some attention, that the quantity of heat produced in the combustion of any given quantity of coals should be increased by mixing the coals with clay, which is certainly an incombustible body; but the phenomenon may be explained in a satisfactory manner.

The heat generated in the combustion of any small particle of coal existing under two distinct forms, namely, in that which is combined with the flame and smoke which rise from the fire, and which, if means are not found to stop it, goes off immediately by the chimney and is lost—and the radiant heat which is sent off from the fire in all directions in right lines:—It is therefore reasonable to conclude, that the particles of clay, which are surrounded on all sides by the flame, arrest a part at least of the combined heat, and prevent its escape; and this combined heat, so arrested, heating the clay red hot, is retained in it, and being changed by this operation to radiant heat, is afterwards emitted, and may be directed and employed to useful purposes. In the composition of fire-balls, the Count thinks it probable that a certain proportion of chaff, of straw cut very fine, or even of saw-dust, might be employed with great advantage.

FULLING OF WOOLLEN CLOTHS (see the method of performing the operation under the article **FULLING**, *Encycl.*) depends, like **FELTING**, so entirely upon the structure of wool and hair, that the following observa-

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tions, which are not unimportant, will be intelligible to every reader who has perused that article in this *Supplement*.

The asperities with which the surface of wool is every where surrounded, and the disposition which it has to assume a progressive motion towards the root, render the spinning of wool, and making it into cloth, difficult operations. In order to spin wool, and afterwards to weave it, we are obliged to cover its fibres with a coating of oil, which, filling the cavities, renders the asperities less sensible; in the same way as oil, when rubbed over the surface of a very fine file, renders it still less rough. When the piece of cloth is finished, it must be cleansed from this oil; which, besides giving it a disagreeable smell, would cause it to soil whatever it came in contact with, and would prevent its taking the colour which is intended to be given to it by the dyer. To deprive it of the oil, it is carried to the fulling-mill, where it is beat with hammers in a trough full of water, in which some clay has been mixed; the clay combines with the oil, which it separates from the cloth, and both together are washed away by the fresh water which is brought to it by the machine; thus, after a certain time, the oil is entirely washed out of the cloth.

But the scouring of the cloth is not the only object in fulling it; the alternate pressure given by the mallets to the piece of cloth, occasions, especially when the scouring is pretty far advanced, an effect analogous to that which is produced upon hats by the hands of the hatter; the fibres of wool which compose one of the threads, whether of the warp or the woof, assume a progressive movement, introduce themselves among those of the threads nearest to them, then into those which follow; and thus, by degrees, all the threads, both of the warp and the woof, become felted together. The cloth, after having, by the above means, become shortened in all its dimensions, partakes both of the nature of cloth and of that of felt; it may be cut without being subject to ravel, and, on that account, we are not obliged to hem the edges of the pieces of which clothes are made. Lastly, As the threads of the warp and those of the woof are no longer so distinct and separated from each other, the cloth, which has acquired a greater degree of thickness, forms a warmer clothing. Knit worsted also is, by fulling, rendered less apt to run, in case a stitch should drop in it.

FULMINATING GOLD. } See *CHEMISTRY, Suppl.*
FULMINATING Silver. } nos 849 and 850.

Mr Berthollet, the inventor of fulminating silver, having contented himself with a general and concise description of this subject, many practical chemists have failed in their attempts to prepare it; and others, forming their opinions from the specimens which they had made, have been exposed to great danger; as will appear from the following relation:

An ounce of fine silver was dissolved in the course of eight hours in an ounce of pure nitrous acid, of the London Pharmacopœia, diluted previously with three ounces of distilled water in a glass matras. The solution being poured off, the residuary black powder and the matras were washed with seven or eight ounces of warm distilled water, and this was added to the solution. The black powder, being gold, was rejected; some gold being thus separable from any silver of commerce.

To the foregoing diluted solution, pure lime-water

Fulling,
Fulminating.

Fulmina-
ting.

prepared with distilled water was added gradually; for the solution ought not to be poured into the lime water. When about thirty pints of lime-water had been expended, and the precipitate had subsided, more lime-water was added, by successive pints, as long as it caused any precipitation. For it was deemed fitter that the precipitation should not be perfected, than that an excess of lime-water should be used; the earthy pellicle of the excessive lime-water being apt to mix with the precipitate. The clear liquor being poured away, the precipitate was poured off, and washed into a filter.

When the saline liquor had drained from it, two ounces of distilled water were poured on the magma; and when this water had passed, fresh portions were successively added and passed, until the whole quantity of water thus expended in washing away the nitrous calcareous salt amounted to a quart.

The filter being then unfolded, to let the magma of oxide of silver spread on the flattened paper, it was placed on a chalk-stone to accelerate the exsiccation, and was gradually dried in the open air; a cap of paper being placed loosely over it to exclude the dust.

When the weather served, the cap was removed, to expose the oxide to the rays of the sun; although this was not deemed necessary; and exsiccation was promoted by cutting the oxide into thin slices. When perfectly dry it weighed 1 oz. 4 dwts. and about one-fifth of it was considered as oxygen.

When aqua ammoniæ puræ of any pharmacopœia is used with this oxide, either in the small quantity which blackens it completely, or in a greater quantity, the black matter which subsides, and which has been represented by systematic writers as the fulminating compound, has no such property, any farther than may be owing to the matter deposited from the alkaline solution during the exsiccation.

The alkaline liquor containing the fulminating silver ought to be poured off from the insoluble powder, and exposed in a shallow vessel to the air. In consequence of the exhalation, black shining crystals form on the surface only, and soon join to form a pellicle. As this pellicle adheres a little to the sides of the vessel, or maintains its figure, the liquor may be poured off by a gentle inclination of the vessel.

This liquor will yield another pellicle in the same way; but the third or fourth pellicle will be paler than the former, and weaker in the explosion. The first pellicles, when slowly dried, explode by the touch of a feather, or by their being heated to about 96°.

The quantity of water in the ordinary aqua ammoniæ puræ renders it less active in the solution of the oxide, and is an impediment to the speedy formation and separation of the fulminating silver; and an experimenter who has often used twenty grains of the oxide to produce successive pellicles of fulminating silver, which may be separately exploded with safety, and who has perceived that the pellicles never explode whilst wet, if they be not heated, would, in all probability, resolve on the following improvement, and expose himself to the unforeseen danger of it.

Distilled water was impregnated with as much pure ammoniac as it could easily retain under the ordinary temperature of the air. A quantity of this strong ammoniacal liquor, equal in bulk to a quarter of an ounce of water, was placed in a small bottle, and 24 grains of

the oxide of silver, ground to fine powder, were added. The bottle, being almost filled, was corked, to prevent the formation of that film which usually appeared in consequence of the exhalation of the ammoniac in other experiments.

Function
||
Fust.

During the solution of the oxide, bubbles of the gaseous kind arose from it, and the solution acquired a blue colour. As no film appeared, the bottle was agitated three or four times in the course of as many hours, in order to promote the solution of a small quantity of blackened oxide which remained at the bottom. The experimenter considering this as an ample provision for twenty different charges, to be exploded in different circumstances, in the presence of the society, intended to pour off the solution into as many small vessels, and to weigh the residuary black powder, after allowing two hours more for the solution.

On the sixth hour he took his usual precaution of wearing spectacles; and observing that a small quantity of black powder still remained undissolved, and that no film was yet formed at the surface, he took the bottle by the neck to shake it; knowing that it might explode by the heat of his hand, if he were to grasp it, and that the explosion in this circumstance might wound him dangerously.

In the instant of shaking, it exploded with a report that stunned him. The bottle was blown into fragments so small as to appear like glass coarsely powdered. The hand which held it was impressed as by the blow of a great hammer, and lost the sense of feeling for some seconds; and about 52 small grains of glass were lodged, many of them deeply, in the skin of the palm and fingers. The liquor stained his whole dress, and every part of the skin that it touched. Thus it appeared that fulminating silver may be made which will explode even when cold and wet, by the mere disturbance of the arrangement of its parts, in the aqueous fluid.

In subsequent experiments, privately and carefully conducted, it seemed that the property of exploding in the cold liquor, by mere commotion, depended on the unusual quantity or proximity of the explosive molecules in a given bulk of the liquor. And the flat bottoms, as well as the sides, of the thick vessels of glass or potters-ware, whether they stood on boards or iron plates, were always beaten to small fragments.

This afforded a curious instance of the possible equilibrium between the powers tending to retain the caloric and those which effect the expulsion of it; and experiments and considerations of this kind seemed to promise a true solution of the phenomena of Rupert's drops.

FUNCTION, a term used in analytics for an algebraical expression, anyhow compounded of a certain letter or quantity with other quantities or numbers; and the expression is said to be a function of that letter or quantity. Thus $a - 4x$, or $ax + 3x^2$, or $2x - a\sqrt{a^2 - x^2}$, or x^c , or e^x , is each of them a function of the quantity x .

FURD-γ-НУСКЕЕСУТ, in Bengal, signifies a paper of description.

FURD-y-Sowal, paper of request.

FUST, in architecture, the shaft of a column, or the part comprehended between the base and the capital, called also the naked.

G.

Gaguedi.

GAGUEDI, a tree peculiar to Lamalmon, in Abyssinia, is thus described by Mr Bruce. The leaves are long, and broader as they approach the end. The point is obtuse; they are of a dead green, not unlike the willow, and placed alternately one above the other on the stalk. The calyx is composed of many broad scales lying one above the other, which operates by the pressure upon one another, and keeps the calyx shut before the flower arrives at perfection. The flower is monopetalous, or made of one leaf; it is divided at the top into four segments; where these end, it is covered with a tuft of down, resembling hair, and this is the case at the top also. When the flower is young and unripe, they are laid regularly so as to inclose one another in a circle. As they grow old and expand, they seem to lose their regular form, and become more con-

fused, till at last, when arrived at its full perfection, they range themselves parallel to the lips of the calyx, and perpendicular to the stamina, in the same order as a rose. The common receptacle of the flower is oblong, and very capacious, of a yellow colour, and covered with small leaves like hair. The stile is plain, simple, and upright, and covered at the bottom with a tuft of down, and is below the common receptacle of the flower.

Gaguedi.

Our author says that he has observed, in the middle of a very hot day, that the flowers unbend themselves more, the calyx seems to expand, and the whole flower to turn itself towards the sun in the same manner as does the sunflower. When the branch is cut, the flower dries as it were instantaneously, so that it seems to contain very little humidity.

G A L V A N I S M.

¹
Galvanism
improperly
called ani-
mal electri-
city.

GALVANISM is the name now commonly given to the influence discovered nearly eight years ago by the celebrated Galvani, professor of anatomy at Bologna, and which, by him and some other authors, has been called *animal electricity*. We prefer the former name, because we think it by no means proved that the phenomena discovered by Galvani depend either upon the electric fluid, or upon any law of animal life. While that is the case, it is surely better to distinguish a new branch of science by the name of the inventor, than to give it an appellation which probably may, and in our opinion certainly does, lead to an erroneous theory.

M. Galvani was engaged in a set of experiments, the object of which was to demonstrate, if possible, the dependence of muscular motion upon electricity. In the course of this investigation, he had met with several new and striking appearances which were certainly electrical; soon after which, a fortunate accident led to the discovery of the phenomena which constitute the chief subject of this article. The strong resemblance which these bore to the electrical facts which he had before observed, led almost irresistibly to the conclusion that they all depended upon the same cause. This opinion he immediately adopted; and his subsequent experiments and reasonings were naturally directed to support it. The splendor of his discovery dazzled the imaginations of those who prosecuted the enquiry; and for some time his theory, in so far at least as it attributed the whole to the agency of the electric fluid, was sanctioned by universal approbation. Of late, however, this opinion has rather lost ground; and there are now many philosophers who consider the phenomena as totally unconnected with electricity.

²
Discovery
of galva-
nism.

³
Object of
this article.

We propose, in the *first* place, to enumerate the chief facts which have been ascertained on the subject; we shall then enquire, whether or not the cause of the appearances be the electric fluid; and, *thirdly*, we shall examine how far it has been proved that this cause is necessarily connected with animal life.

Whilst Galvani was one day employed in dissecting a frog, in a room where some of his friends were amusing themselves with electrical experiments, one of them ha-

ving happened to draw a spark from the conductor at the same time that the professor touched one of the nerves of the animal, its whole body was instantly shaken by a violent convulsion. Astonished at the phenomenon, and at first imagining that it might be owing to his having wounded the nerve, he pricked it with the point of his knife, to assure himself whether or not this was the case, but no motion of the frog's body was produced. He now touched the nerve with the instrument as at first, and directed a spark to be taken at the same time from the machine, on which the contractions were renewed. Upon a third trial, the animal remained motionless; but observing that he held his knife by the handle, which was made of ivory, he changed it for a metallic one, and immediately the movements took place, which never was the case when he used an electric substance.

After having made a great many similar experiments with the electrical machine, he resolved to prosecute the subject with atmospheric electricity. With this view he raised a conductor on the roof of his house, from which he brought an iron wire into his room. To this he attached metal conductors, connected with the nerves of the animals destined to be the subjects of his experiments; and to their legs he fastened wires which reached the floor. These experiments were not confined to frogs alone. Different animals, both of cold and warm blood, were subjected to them; and in all of them considerable movements were excited whenever it lightened. These preceded thunder, and corresponded with its intensity and repetition; and even when no lightning appeared, the movements took place when any stormy cloud passed over the apparatus. That all these appearances were produced by the electric fluid was obvious.

Having soon after this suspended some frogs from the iron palisades which surrounded his garden, by means of metallic hooks fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily as if from a shock of electricity. Not doubting that the contractions depended on the electric fluid, he at first suspected that they were connected with changes in the state of the atmosphere. He soon

found, however, that this was not the case; and having varied, in many different ways, the circumstances in which the frogs were placed, he at length discovered that he could produce the movements at pleasure by touching the animals with two different metals, which, at the same time, touched one another either immediately or by the intervention of some other substance capable of conducting electricity.

All the experiments that have yet been made may be reduced to the following, which will give the otherwise uninformed reader a precise notion of the subject.

Lay bare about an inch of a great nerve, leading to any limb or muscle. Let that end of the bared part which is farthest from the limb be in close contact with a bit of zinc. Touch the zinc with a bit of silver, while another part of the silver touches, either the naked nerve, if not dry, or, whether it be dry or not, the limb or muscle to which it leads. Violent contractions are produced in the limb or muscle, but not in any muscle on the other side of the zinc.

Or, touch the bared nerve with a piece of zinc, and touch, with a piece of silver, either the bared nerve, or the limb; no convulsion is observed, till the zinc and silver are also made to touch each other.

4
Has engaged much scientific attention.

A fact so new, illustrated by many experiments and much ingenious reasoning, which Professor Galvani soon published, could not fail to attract the attention of physiologists all over Europe; and the result of a vast number of experiments, equally cruel and surprising, has been from time to time laid before the public by Valli, Fowler, Monro, Volta, Humboldt, and others.

Frogs, unhappily for themselves, have been found the most convenient subjects for these experiments, as they retain their muscular irritability and susceptibility of the galvanic influence very long. Many hours after they have been decapitated, or have had their brain and spinal marrow destroyed, strong convulsions can be produced in them by the application of the metals. A leg separated from the body will often continue capable of excitement for several days. Nay, very distinct movements have been produced in frogs pretty far advanced in the process of putrefaction. Different kinds of fishes, and many other animals both of cold and warm blood, have been subjected to similar experiments, and have exhibited the same phenomena; but the warm blooded animals lose their susceptibility of galvanism, as of every other stimulus, very soon after death.

5
The metals.

Almost any two metals will produce the movements; but, it is believed, the most powerful are the following, in the order in which they are here placed: 1. Zinc; 2. Tin; 3. Lead; in conjunction with, 1. Gold; 2. Silver; 3. Molybdena; 4. Steel; 5. Copper. Upon this point, however, authors are not perfectly agreed.

The process by which these singular phenomena are produced, consists in effecting, by the use of the exciting apparatus, a mutual communication between any two points of contact, more or less distant from one

another, in a system of nervous and muscular organs. The sphere of this mutual communication may be regarded as a complete circle, divided into two parts. That part of it which consists of the organs of the animal under the experiment, has been called *the animal arc*; that which is formed by the galvanic instruments has been called *the excitatory arc*. The latter usually consists of more pieces than one; of which some are named *stays, braces, &c.* others *communicators*, from their respective uses.

A very numerous train of experiments on galvanism has been made by a committee of the Physical and Mathematical Class of the National Institute of France; and as their report comprehends a vast number of the most important facts which are yet known on the subject, we shall present our readers with the substance of it (A).

7
Experiments of the French institute.

The immense mass of matter which resulted from the experiments of the committee, is, in their report, presented, not in the order in which the experiments were made, but in a sort of classification, by means of which a more distinct knowledge of the subject is obtained at one view. The facts are arranged under these six heads. 1st, Results of the different combinations and dispositions of the parts of the *animal arc*. 2^d, Account of what has been observed of the nature and the different dispositions of the *excitatory arc*. 3^d, Circumstances not entering into the composition of the galvanic circle, which, nevertheless, by their influence, modify, alter, or entirely prevent the success of the experiments. 4th, Means proposed for varying, diminishing, or restoring the sensibility to galvanism. 5th, Attempts to compare the phenomena of galvanism with those of electricity. 6th, Additional experiments, performed by M. Humboldt, in the presence of the members of the committee; which have a reference to several of the proofs stated in the foregoing articles.

I. To the number of twenty experiments were made on the *animal arc*. The first seven of these were directed to ascertain the relations between the nerves and those muscles over which they are distributed. In the last thirteen, the nerves were cut asunder, or subjected to ligatures; the section or ligature being always between the extremities of the arc. Nerves taken from different animals, or from different parts of the same animal, and joined in one and the same arc, were among the particular subjects of these experiments; as were also the solitary nerve, and the solitary muscle, included between the extremities of the *excitatory arc*. There were interposed, too, in the course of these experiments, portions of nerves, and of muscles, distinct from those parts. And, in some of the experiments, the animal was without the skin and the epidermis.

The following are inferences which have been deduced from these experiments:

1. The animal arc may consist either of nerves and muscles together, or of nerves alone, without muscles (B).
2. Nerves are, therefore, the essential part of the animal

9
Inferences.

(A) The members of the committee were, M. M. Coulomb, Sabbatier, Pelletan, Charles, Fourcroy, Vauquelin, Guyton, *alias* Morveau, and Hallé. M. M. Venturi, De Modene, and M. Humboldt, assisted in the experiment.

(B) We are strongly inclined to doubt the truth of this proposition. Dr Fowler was at first led to think that contractions could be excited in a limb without the metals having any communication with it, except through the medium of the nerve. Recollecting, however, that a very small quantity of moisture serves as a conductor of galvanism, he suspected, and our opinion perfectly coincides with his, that in every case where contractions

are

animal arc; for the muscles are always more or less interferred by the nerves; and are, consequently, in part, a nervous organ.

3. All the parts of the animal arc must be either mutually continuous, or at least contiguous to one another. But even contiguity is sufficient to enable the galvanic phenomena to take place.

4. The section or ligature of a nerve interrupts not the galvanic phenomena, if the parts which are cut asunder or bound up still remain in close contiguity to one another.

5. No diversity of the parts forming the animal arc, though these be taken from different parts of the same animal, or even from different animals, will have power to impair its galvanic susceptibility, provided only that these parts be still mutually contiguous.

6. If the integrity or galvanic susceptibility of the animal arc be suspended by the separation of any of its parts to some distance from one another, it may be restored by the interposition of some substances, not of an animal nature, between the divided parts. Metallic substances are in particular fit for this use. But the mutual contiguity of all the substances entering into the composition of the arc must ever be carefully preserved. Mr Humboldt discovered that a bit of fresh morelle (*Helvella mitra* Linn.) will supply the place of a part of the nerve.

7. The muscular organs which indicate, by contrac-

tion, the presence of the galvanic influence, are always those in which the nerves of a complete animal arc have their ultimate termination.

From this it follows, that the muscles affected by galvanism are always those corresponding to that extremity of the arc which is the most remote from the origin of the nerves of which it is composed.

8. When all the nerves of the animal arc originate towards one of its extremities, then only those muscles which correspond with the opposite extremity are susceptible of galvanic convulsions.

9. When an animal arc consists of more than one system of different nerves, which have all their origin about the middle of the arc, then will the muscles of these several systems of nerves be moved alike at both the extremities of the arc.

10. It seems likewise to appear, from a variety of these experiments, that the opinion of those is inadmissible, who ascribe the phenomena of galvanism to the concurrence of two different and reciprocally corresponding influences, one belonging to the nerve, the other to the muscle, and who compare the relations between the nerve and the muscle, in these phenomena, to those between the interior and the exterior coating of the Leyden phial.

11. It appears, lastly, that the covering of the epidermis, in the entire animal body, acts as an obstacle to the decisive display of the effects of galvanism; and that,

are produced in a limb without any apparent communication between the metals and the muscles, except through the medium of a nerve, the communication is in fact completed by the moisture upon the surface of the nerve. In this case, the animal arc may be considered as consisting of three pieces, disposed in the following order; the nerve, the muscle, and the water adhering to the surface of the nerve. The latter, indeed, ought rather to be considered as a part of the excitatory arc. "When a nerve (says Dr Fowler), which for some time has been detached from surrounding parts, is either carefully wiped quite dry with a piece of fine muslin, or (left this should be thought to injure its structure) suffered to remain suspended till its moisture has evaporated, no contractions can be excited in the muscles, to which it is distributed, by touching it alone with any two metals in contact with each other; but if it be again moistened with a few drops of water, contractions instantly take place. And, in this way, by alternately drying and moistening the nerve, contractions may at pleasure be alternately suspended and renewed for a considerable time. It may, indeed, be contended, that the moisture softened, and thus restored elasticity and free expansion to the dried cellular membrane surrounding the fibres, of which the trunk of a nerve is composed; and thus, by removing constraint, gave free play to their organization.

"But from observing, that in every other instance where contractions are produced by the mutual contact of the metals, a conducting substance is interposed between them and the muscles as well as between them and the nerve; I think it would be unphilosophical not to allow, that, in the instance in question, the moisture, adhering to the surface of the nerve, formed that requisite communication between the metals and the muscles." We know of no accurate experiment by which it has ever been shewn, that contractions can be produced in a limb without a communication being established between the metals and nerve, and again between the muscles and the metals, either directly, or through some medium capable of conducting galvanism.

To remove the only objection which can be made to Dr Fowler's experiment, and of which we have seen that he was himself aware, namely, that the nerve while dry is incapable of performing its functions, we repeated it in the following manner: A small, but vigorous and lively, male frog was decapitated, and the sciatic nerve being laid bare from the knee upwards, was cut through where it passes out of the pelvis. Fifteen minutes after the head was cut off, the nerve having been cautiously separated from the surrounding parts, and coated with tinfoil in the usual manner, a silver probe was applied to it and its coating, without any other communication with the muscles, and strong contractions took place in the leg. The nerve was now very carefully dried with a piece of fine linen, and the probe was applied as before to the tinfoil and the nerve; no movement whatever took place. Things remaining precisely in this situation, one end of the probe being still in contact with the nerve and its coating, the other end was applied to the muscles of the thigh, and the leg immediately contracted as strongly as ever. Upon moistening the nerve, the contractions were again produced by applying the probe to the nerve and tinfoil alone. We find from this experiment, which we have several times repeated with the utmost care, and with the same result, that the dry nerve retained its functions completely. This appears to us perfectly decisive of the question.

that, though from its extreme tenuity, it may not altogether prevent these effects, yet it cannot but very materially diminish them.

10
Experi-
ments on
the excita-
tory arc.

II. The *Excitatory Arc* is usually formed of three different pieces, made of different metals. Of these, one must be in contact with the nerve; the other must touch the muscle; and the third must form the mean of communication between these two. This arrangement, though not indispensably necessary, is at least the most convenient.

In respect to the excitatory arc, the committee examined, 1st, The application of metallic substances to form it: in respect to which they endeavoured to ascertain the number and the diversity of the pieces of metal of which this arc may be composed; the metallic mixtures or alloys which are capable of being employed for this use; the particular degree of the friction of one metal upon another, which is favourable to the exhibition of the phenomena; the different states, in respect to galvanism, of metals differently mineralized. 2dly, The effects of the use of carbonic substances in forming the excitatory arc. 3dly, The effects in the same formation, of bodies, which are either non-conductors, or else very imperfect conductors of electricity, such as jet, asphaltus, sulphur, amber, sealing-wax, diamond, &c. 4thly, The consequences of the interposition of water, and of substances moistened with water, between the different parts of the excitatory arc. In forming their excitatory arcs, too, they made themselves the chord of the arc; they introduced into it animal substances which had lost their vitality; they rubbed the supporters with the dry fingers, so as to mark them with nothing but the traces of the perspiration from the skin. They made, likewise, some experiments for the purpose of ascertaining the relations between, on the one hand, the extent and magnitude of the surfaces of the parts composing the arc, and, on the other, the effects produced by its energy. From

their experiments they have also drawn some inferences concerning the relative efficiencies of the several constituent parts of the exciting arc. It is impossible for us here to relate in detail all this train of experiments. The following corollaries express the substance of those general truths, which their authors were led to infer from them.

11

1. The excitatory arc possesses the greatest power of galvanism, when it is composed of at least three distinct pieces; each of a peculiar nature: the metals, water, and humid substances, carbonaceous matters, and animal substances, stripped of the epidermis, being the only materials out of which these pieces may be formed.

2. Nevertheless the excitatory arc appears to be not destitute of exciting energy, even when it consists but of one piece or of several pieces, all of one proper substance (c). In general it must be owned, identity of nature in the constituent pieces, and particularly in the supports forming the extremities of the arc, diminishes, in a very sensible manner, its galvanic energy.

3. The slightest difference of nature induced upon the parts, whether by any feeble alloy, or by friction with extraneous substances, is at any time sufficient to communicate to the excitatory arc that full power in which the identity of its composition may have made it defective.

4. As the animal arc is susceptible of being in part made up of metallic substances, or such others as are adapted to enter into the composition of the excitatory arc; so, on the other hand, the excitatory arc admits of being in part formed of those substances which are the proper components of the animal arc.

5. The energies of both the excitatory and the animal arcs are alike suspended by the separation of their component parts, or at least by the separation of these parts to a certain distance.

6. Even the smallest degree of moisture is sufficient to

to

(c) We do not think it has ever been proved, that one piece of metal, or several pieces of the same metal, are capable of forming the excitatory arc. It is admitted on all hands, that the slightest alloy communicates galvanic energy to a piece of metal; that is, renders it capable of forming the excitatory arc. It is also known, that the metallic oxides are much less perfect conductors of galvanism than their corresponding reguli, to make use of an antiquated expression. It appears to us, that in all cases where one metal appears to act, more especially where friction with the fingers, or breathing on a piece of metal formerly inert, give it galvanic powers; in all these cases, we think it probable that a slight degree of oxidation, produced in some part of the surface of the metal, gives it activity by destroying the homogeneity of its nature. We do not find that this circumstance has been in general sufficiently attended to. Dr Wells having discovered that charcoal acts powerfully as an exciter when applied along with a metal, found that by friction it also can be rendered capable of acting singly. What change is thus produced in it we can only conjecture; but that it is something which destroys the identity of its structure, rendering it in some measure a heterogeneous substance, must be admitted.

Candour forces us to acknowledge, that in one of Mr Humboldt's experiments, it seems very difficult to point out any want of homogeneity in the exciting arc. He put into a china cup some mercury exactly purified; he placed the whole near a warm stove, in order that the entire mass might assume an equal temperature: the surface was clear without the appearance of oxidation, humidity, or dust. A thigh of a frog, prepared in such a manner that a crural nerve and a bundle of muscular fibres of the same length hung down separately, was suspended by two silken threads above the mercury. When the nerve alone touched the surface of the metal, no irritation was manifested; but as soon as the muscular bundle and the nerve touched the mercury together, they fell into convulsions so brisk, that the skin was extended as in an attack of tetanus. This is by far the most decisive experiment which has been tried on the same side of the question; but as it must be admitted, that in most cases two metals are absolutely necessary, and that a single metal often derives activity from circumstances so slight, that we could not *a priori* have expected that they were capable of producing any change; we feel ourselves compelled to conclude, that in M. Humboldt's experiment some similar very slight circumstance had escaped unobserved; perhaps some gilding, or ornaments with metallic colours, in a state of oxidation.

to join the parts of the excitatory arc, and to determine their effects upon the animal arc.

7. The influence upon the state of the atmosphere, and of surrounding circumstances, upon the success of the experiments of galvanism, is, consequently, very great. In order, therefore, to perform these experiments with due accuracy, the state of the hygrometer, and of other meteorological instruments, must be vigilantly inspected during their progress; and the influence of the persons making the experiment upon the sphere within which it is made, must likewise be carefully attended to.

8. The experiments which were made to ascertain the nature of the animal arc, together with those made upon the excitatory arc, with a view to the comparison of the effects of the flesh of animals, with or without the epidermis, and of the different effects of this epidermis, when it is wet and when it is dry, appear to suggest to us, that the epidermis is one of those substances which diminish or interrupt the efficacy of the excitatory arc. The epidermis is, as well as the hairs and bristles of animal bodies, among the number of those substances which deserve the appellation of *idio-electrics*.

9. Examine the substances which are fit for the formation of the excitatory arc, and you will find that the greater part of those which have been successfully put to this use are substances capable of acting as conductors of the electrical fluid; but that the substances which interrupt the operation of galvanism are generally such as are well known also to resist the transmission of electricity.

10. Lastly, it appears, that the galvanic energy depends, not only upon the nature and arrangement of the component parts of the excitatory arc, but on their extent too, and on the magnitudes of their transmitting surfaces.

III. The committee appear to have used no less care and discernment in experiments upon those circumstances which, though different from the structure of the galvanic circle and its two constituent arcs, have, however, a *decisive influence upon the exhibition of the phenomena of galvanism*. Some curious observations were made on the differences in the state of the parts exposed to the galvanic action. It was ascertained, that frogs fresh from the ditches did by no means exhibit the same phenomena as those which had been during some days preserved in the house; nor did the limbs of animals, when recently stripped of the skin, present the same appearances as after they had been subjected to a variety of galvanic experiments; nor were the same effects to be produced upon the parts of animal bodies which, after a certain number of trials, had been left for a while at rest, and then taken up again, as upon those which had been subjected to one continued train of experiments. The committee next examined the variations in the success of the experiments upon a strong lively frog, which may be produced by varying the mode in which the *communicator* is carried from the one *supporter* to the other: when the communicator is brought into contact with the supporter, or is withdrawn from actual contact with it; when the *communicator* is brought slowly, or when it is brought rapidly, into contact with the *supporter*; the effects are nearly the same: and a smart convulsion is, in all these cases, produced at the moment of the com-

mencement of the mutual contact, or of its cessation. But when the frog is fatigued, the effects are different. These successive experiments likewise affect the results of one another, by means even of their succession solely. And they are also naturally subject to be influenced by the nature of the media amidst which they are performed; such as common air, water, an electrical atmosphere. The following are the inferences which have been deduced from this class of these experiments.

1. In many cases the galvanic energy is excited by exercise, is exhausted by continued motion, is renovated by rest. 13
Inferences.

2. The multiplicity of the causes by which the experiments of galvanism are liable to be influenced to success or failure, is so great, that we cannot, as yet, be too cautious in either rejecting or believing these accounts which we hear of the success of any such experiments; unless when we are able accurately to appreciate all the influencing circumstances.

3. This is remarkably confirmed by a fact, which the committee have related in their paper, and which respects the continuation of the galvanic spasm.

The communicator being supported by the hand, and resting, seemingly, without change of position, still upon the same point of contact, there is known to take place a real change in the galvanic contact, although the communicator have remained thus apparently motionless.

From this, it may be farther inferred, that the smallest possible change in the relative situations of the parts of the galvanic circle and the excitatory arc, is capable of producing an effect upon the susceptible animal, and of occasioning mistakes in regard to the success of the experiment, if the utmost care be not taken to notice and estimate every variation that can happen.

4. The truth of the foregoing proposition is farther confirmed by the experiments upon the manner in which the galvanic movements are affected by the advancing or the withdrawing of the communicator. For these experiments fully evince the necessity for the most vigilant observation of every movement in the process of an experiment, not only collectively, but in their succession, and at the different periods of the operation.

5. It should seem that there are, in the formation of the excitatory arc, independently of its modes of acting in the galvanic operations, certain enervating, and certain exciting dispositions; of which some not only augment or diminish the energy in the present instance, but, besides, dispose the animal to a greater or a smaller susceptibility, under subsequent experiments.

6. In order to accuracy of experiment, and to the correct ascertaining of the effects of an experiment, it is of great importance to know the precise state of the animal, the manner in which it has been preserved and sustained to the present moment, the state of the atmosphere, particularly as it is indicated by the hygrometer, by the barometer, the thermometer, and the electrometer.

7. It were to be wished, that in making a statement of experiments of different sorts, these should be arranged in the order of their efficacy, and that there might thus be formed a *galvanic scale*, which should help us to determine the precise degree of the galvanic susceptibility.

fusceptibility of any animal in this or that particular state or position, should direct us in subjecting every such animal only to experiments suitable to its particular fusceptibility; should enable us to estimate, from the *efficacy* or *inefficacy* of our experiments, the galvanic value of the circumstances in which we every day find ourselves, and should enable us to judge when the success or miscarriage of an experiment can afford room for certain conclusions absolutely negative or affirmative.

14
Experiments on the galvanic fusceptibility of animal bodies, &c.

IV. In their experiments upon *the means of varying, diminishing, and renewing the fusceptibility of animal bodies* to the influence of galvanism, the committee examined, 1st, the influence of electricity upon that fusceptibility; 2d, the effects of the muscular organs, and of certain liquors, such as alcohol, the oxygenated muriatic acid, the solutions of potash and opium, upon the galvanic properties; 3d, and at the medical school of Paris they made a number of experiments, in order to ascertain what new modifications the galvanic energy undergoes in various cases of suffocation or asphyxia. These last-mentioned experiments were made upon hot-blooded animals, of which some were reduced into the state of asphyxia by submerision, some by strangulation, some by the action of gases, while others were killed *in vacuo* by the discharge of the electric spark. In that suffocation which was produced by sulphurated hydrogenous gas, by carbonic vapours, and by submerision, in which the animal was suspended by the hinder feet, the galvanic fusceptibility was entirely destroyed. The galvanic fusceptibility was only suspended by suffocation produced by the pure carbonic acid confined under mercury. It was diminished, but not destroyed, in those cases of suffocation, which were occasioned by sulphurated hydrogenous gas that had lost a portion of its sulphur, by gas ammoniac, gas azote, or such gases as had been exhausted of their pure air by respiration; and the same thing was found to take place in animals which had perished by total submerision. But the galvanic fusceptibility survived unaltered in suffocations brought on by submerision in mercury, by pure hydrogenous gas, by carbonated hydrogenous gas, by oxygenated muriatic acid, by sulphureous acid; as also when the suffocation was occasioned by strangulation, by the abstraction of the air in the air-pump, or by discharges from an electrical battery. The results of the experiments at the medical school suggested the following reflections:

15
Reflections.

1. Though it be true that all cases of suffocation resemble one another in the privation of respirable air, and in the suspension of the functions of respiration, and of the circulation of the blood; yet, in their other circumstances, they are subject to great differences, arising from diversity of nature in the substances by which they are occasioned.

2. Of these causes, some appear to act with a more thorough efficacy, penetrating at once all parts of the nervous and muscular systems. Others again seem to act but superficially, producing only pulmonary asphyxia, with its immediate effects.

3. One of the most remarkable changes not confined to the organs of respiration, consists in the alterations produced on the galvanic fusceptibility. In that respect the various cases of asphyxia differ greatly one from another.

4. The state of the irritability of the muscles, when examined by means of bodies, the mechanical action of which causes the muscles to contract by irritating them, is far from always corresponding to the state of their galvanic fusceptibility.

5. Lastly, the causes of suffocation or asphyxia, do not act upon all parts of the muscular system in the same manner; but the heart is very often found in a state extremely different from that of the other muscles.

V. *The comparison between the phenomena of galvanism and those of electricity* is perhaps one of the most interesting objects of attention in the whole body of animal physiology. It is well known that Galvani accidentally led to his discovery by observing the motions of some frogs, at a certain distance from an electrical machine discharging sparks. The committee from the institute made, therefore, some attempts to ascertain the relations between electricity and galvanism. Having first paid due attention to the fusceptibility of animals toward the influence of electricity, they then sought to discover to what precise degree animals divested of the natural covering of the epidermis were liable to be affected by the variations of the electrical fluid in the atmosphere around them. Next, comparing the fusceptibility of electricity with the fusceptibility of galvanism, they perceived that quantities of the electrical fluid, such as are still capable of being very accurately measured by the electrometer, are, however, often too weak to act upon a frog that retains the most perfect sensibility to all the energy of galvanism. The members of the committee purpose to prosecute farther their experiments upon this part of the subject.

16
Comparison of the phenomena of galvanism with those of electricity.

VI. The following are the general results of the experiments made by M. Humboldt in the presence of the committee:

17
Results of some experiments by Humboldt.

1. There is no truth in the assertion of certain physiologists, that the experiments of galvanism fail when tried upon the heart and those other muscles of which the contractions depend not upon volition; for these organs have been found to be actually subject to the influence of galvanism (D).

2. The effects of galvanism are liable to be interrupted by the constriction of a nerve, whenever both the nerve and the constricting ligature are enveloped in the flesh of the animal body (E).

3. The powers of the exciting arc may be renovated or destroyed, even though its supporters remain the same, and although the extremities of the arc be unchanged. Only the relations of the intermediate matters require to be altered.

4. There are atmospheres of galvanism.

5. There are substances which, though in an eminent manner conductors of electricity, yet interrupt the motions of galvanism.

M. Humboldt had performed also other experiments which,

(D) This was demonstrated six years ago by Dr Fowler.

(E) Dr Valli made this observation soon after the discovery of galvanism.

which, when he attempted to repeat them before the committee, could not be brought to succeed, on account, as was supposed, of the season of the year.

Such are the principal results of this valuable train of experiments upon galvanism. From them our readers will perceive that this interesting subject is still very imperfectly understood, and will form some idea of the importance of the discoveries which a diligent prosecution of it promises to the philosopher and the physician.

The effects of galvanism upon some of the organs of sense are no less striking than those which we have seen it capable of producing upon the muscles.

If the upper and under surfaces of the tongue be coated with two different metals, and these be brought into contact with each other, a peculiar sensation, resembling taste, is produced in the tongue the moment that the metals touch each other. With the greater number of metals this sensation is scarcely perceptible; but with zinc and gold, zinc and silver, or zinc and molybdena, it is very strong and disagreeable. Dr Fowler thinks it is strongest with zinc and gold; to us it appears a good deal stronger with zinc and silver. It is sensibly stronger when the zinc is applied to the upper, and the silver to the under surface of the tongue, than when this order is inverted. The sensation is most distinct when the tongue is of the ordinary temperature, and the metals of the same temperature with the tongue. Any considerable increase or diminution of heat in either greatly lessens the effect. Mr Subsir of Berlin, in his *Theorie des Plaisters*, p. 155, (published in 1767) takes notice of the disagreeable taste produced by silver and lead in contact upon the tongue. This is the first instance of galvanism that had been made public.

To ensure complete success to the experiment, the metals ought to be allowed to remain some time in contact with the tongue before they are made to touch each other, that the taste of the metals themselves may not be confounded with the sensation produced by their mere contact. Whatever has a tendency to blunt the sensibility of the tongue, as opium, alcohol, acids, and the like, diminishes the effect of the metals.

It is difficult to describe the sensation thus produced accurately. It has been called *subacid*; but we think it more nearly resembles the effect produced by allowing a grain or two of nitre to lie upon the tongue for some time, than any other taste with which we are acquainted. Joined to this, there is evidently a metallic taste, which varies with the metal employed; but we are inclined to consider this as the ordinary effect of the metals upon the tongue, which cannot be perfectly distinguished from that occasioned by their mutual contact.

This taste can also be produced by applying one of the metals to the tongue, and the other to any part of the Schneiderian membrane. Professor Robison has made many experiments of this kind, the result of which is contained in a letter to Dr Fowler. "I find (says he), that if a piece of zinc be applied to the tongue, and be in contact with a piece of silver which touches any part of the lining of the mouth, nostrils, ear, urethra, or anus, the sensation resembling taste is felt on the tongue. If the experiment be inverted, by applying the silver to the tongue, the irritation produced by the zinc is not sensible, except in the mouth and the

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urethra, and is very slight. I find the irritation by the zinc strongest when the contact is very slight, and confined to a narrow space, and when the contact of the silver is very extensive, as when the tongue is applied to the cavity of a silver spoon. When the zinc touches in an extensive surface, the irritation produced by a narrow contact of the silver is very distinct, especially on the upper side of the tongue, and along its margin. This irritation seems to be mere pungency, without any resemblance to taste, and it leaves a lasting impression like that made by caustic alkali.

"When a rod of zinc, and one of silver, are applied to the roof of the mouth, as far back as possible, the irritations produced by bringing their outer ends into contact are very strong, and that by the zinc resembles taste in the same manner as when applied to the tongue."

M. Volta found, that when a tin cup, filled with an alkaline liquor, is held in one or both hands previously moistened with water, if the point of the tongue is dipped in the liquor, an acid taste is perceived. This is at first distinct and pretty strong, but gradually yields to the alkaline taste of the liquor. The acid taste is still more remarkable, when, instead of an alkaline liquor, an insipid mucilage is made use of. The same philosopher found, that when a cup made of tin, or, what is better, of zinc, was filled with water, and placed upon a silver support, if the point of the tongue was applied to the water, it was found quite insipid, till he laid hold of the silver support, with the hand well moistened, when a very distinct and very strong acid taste was immediately perceived.

If one of the metals be applied to the tongue, and the other to the ball of the eye, a pale luminous flash is perceived when they are brought into contact with each other, and the sensation resembling taste is at the same time produced in the tongue. A flash is, in like manner, produced when one of the metals is applied to the eye, and the other to any part of the palate, fauces, or inside of the cheek. This experiment requires a good deal of attention in the performance; care must be taken not to press the piece of metal against the ball of the eye, lest a flash should be produced by the mere mechanical pressure. It should be cautiously introduced between the eye-lids, till it just touch any part of the ball; and it should be allowed to remain in that situation for some time before it is brought into contact with the other piece of metal, that the parts may be so far accustomed to it as to admit of the sensations produced being properly attended to. The experiment succeeds very well with tin and silver; but the flash is more bright when zinc and gold are used. The piece of metal which is applied to the ball of the eye must be finely polished, otherwise the mechanical irritation is sometimes so great as to prevent the flash from being perceived. Dr Robison has observed, that the brightness of the flash corresponds with the extent of contact of the metal with the tongue, palate, fauces, or cheek.

If a piece of one of the metals be placed as high up as possible between the gums and the upper lip, and the other in a similar situation with respect to the under lip, a very vivid flash of light is observed at the moment that they are brought into contact, and another at the instant of their separation. While they remain in contact, no flash is observed.

When a rod of silver is thrust as far as possible up

one of the nostrils, and then brought into contact with a piece of zinc placed upon the tongue, a very strong flash of light is produced in the corresponding eye at the instant of contact. We have sometimes imagined that the flash in this experiment was produced before the metals actually touched; but in this we may have been deceived.

The following curious experiment was first made by Professor Robison: "Put a plate of zinc into one cheek, and a plate of silver (a crown piece) into the other, at a little distance from each other. Apply the cheeks to them as extensively as possible. Thrust in a rod of zinc between the zinc and the cheek, and a rod of silver between the silver and the other cheek. Bring their outer ends slowly into contact, and a smart convulsive twitch will be felt in the parts of the gums situated between them, accompanied by bright flashes in the eyes. And these will be distinctly perceived before contact, and a second time on separating the ends of the rods, or when they have again attained what may be called the *striking distance*. If the rods be alternated, no effect whatever is produced."—The flashes produced in this last experiment are rather more vivid than any which we have been able to excite by the other methods. The convulsive twitches are very distinct, and somewhat painful, but quite different from the sensation produced by an electric shock. If the edges of the tongue be allowed to touch the plates of metal in the cheeks, the sensation resembling taste is felt very strongly; but this does not in the least impair the other effects of the experiment.

No method has yet, we believe, been discovered of applying the galvanic influence so as to affect the senses of smelling or hearing. We have tried many experiments with this view, chiefly on the organs of smelling, but hitherto without any success (F). Neither has the sense of touch been affected by it, unless, indeed, the following experiment be considered in that view: Let a small portion of the cuticle be removed from any part of the body by a sharp knife, and carry the incision to such a depth that the blood shall just begin to ooze from the cutis vera. Let a piece of zinc be applied here, and a piece of silver to the tongue; when they are brought into contact, a very smart irritation will be felt at the wound.

Some very singular facts of this kind have been discovered by M. Humboldt, who had the resolution to make himself the subject of many well-devised experiments. One of the most remarkable of these is the following: He caused two blistering plasters to be applied on the deltoid muscle of both his own shoulders. When the left blister was opened, a liquor flowed out, which left no other appearance on the skin than a slight varnish, which disappeared by washing. The wound was afterwards left to dry up: this precaution was necessary, in order that the acrid humour which the galvanic irri-

tation would produce, might not be attributed to the idiosyncrasis of the vessels. This painful operation was scarcely commenced on the wound, by the application of zinc and silver, before the serous humour was discharged in abundance; its colour became visibly dark in a few seconds, and left on the parts of the skin where it passed traces of a brown inflamed red. This humour having descended towards the pit of the stomach, and stopped there, caused a redness of more than an inch in surface. The humour, when traced along the epidermis, left stains, which, after having been washed, appeared of a bluish red. The inflamed places having been imprudently washed with cold water, increased so much in colour and extent, that M. Humboldt, as well as his physician Dr Schallerer, who assisted at these experiments, entertained some apprehension for the consequences.

Having now taken notice of the principal facts that are hitherto known in galvanism, we proceed to consider some of the leading opinions on the subject.

The first writers upon the discovery of Galvani seem almost universally to have taken it for granted, that the phenomena depend on the electric fluid; and leaving this very important question behind them, proceeded to explain how this fluid produces such effects. The celebrated discoverer of this influence himself considers a muscle as the perfect prototype of a Leyden phial. When a muscle contracts upon a connection being formed, by means of one or more metals between its external surface and the nerve which penetrates it, M. Galvani contends, that, previously to this effect, the inner and outer parts of the muscle contain different quantities of the electric fluid; that the nerve is consequently in the same state, with respect to that fluid, as the internal substance of the muscle; and that, upon the application of one or more metals between its outer surface and the nerve, an electrical discharge takes place, which is the cause of the contraction of the muscle. Thus the nerve is supposed to perform the office of the wire connected with the internal surface of the phial; and the excitatory arc is considered merely as a conductor.

This theory appears to us just as incapable of explaining the phenomena of galvanism as it is inconsistent with the known laws which regulate the motions of the electric fluid. We shall not consider it minutely; for we hope it will soon appear highly probable, if not certain, that the electric fluid has no share in the production of the phenomena in question. If this be the case, all the different modifications of that theory must of course fall to the ground. At present we shall content ourselves with asking the following questions:

1. How is it possible for the electric fluid to be condensed in a muscle, which is wholly surrounded by substances capable of conducting that fluid?
2. If we suppose there is some non-descript non-conducting substance placed between the external and internal

(F) Professor Robison has long ago observed, that the flavour of a pinch of snuff taken from a box made of tin-plate, which has been long in use, so that the tin coating is removed in many places, is extremely different from that of snuff when taken from a new box, or a box lined with tin-foil. The same difference is observed when we rub a piece of pure tin, or of pure iron and a half worn tinned plate, with the finger. Also, if we rub a cast steel razor, and a common table knife consisting of iron and steel welded together. This is surely owing to a cause of the same kind.

ternal parts of a muscle, which may admit of the one being positively, and the other negatively electrified at the same time—how comes it to pass that a discharge does not take place, and a consequent contraction ensue, when any substance whatever, capable of conducting the electric fluid, is interposed between the nerve and the external surface of the muscle? For example, when the nerve and muscle are laid bare, and the animal thrown into water; or when the nerve is cut through, and the end applied to the external surface of the muscles.

3. How does it happen, when one discharge actually takes place, in consequence of the application of the excitatory arc, that the balance is not instantly restored? That this does not happen, appears by the same muscle and nerve being capable of producing many hundreds of similar, and equally strong discharges, without any apparent means of the equilibrium being again disturbed.

We have never seen any answers to these questions which appeared to us at all satisfactory; and till we have seen them answered, we must be excused for disbelieving M. Galvani's theory.

One of the earliest writers, and one of the most assiduous investigators of the phenomena of galvanism, is Dr Valli. He differs in opinion from Galvani upon several points; but agrees with him in thinking electricity and galvanism the same. Let us consider the proofs by which he supports this doctrine.

"I have asserted (says he), that the nervous fluid is the same with electricity, and with good reason; for

"Substances which conduct electricity are conductors likewise of the nervous fluid.

"Substances which are not conductors of electricity do not conduct the nervous fluid.

"Non-conducting bodies, which acquire by heat the property of conducting electricity, preserve it likewise for the nervous fluid.

"Cold, at a certain degree, renders water a non-conductor of electricity as well as of the nervous fluid.

"The velocity of the nervous fluid is, as far as we can calculate, the same with that of electricity.

"The obstacles which the nerves, under certain circumstances, oppose to electricity, they present likewise to the nervous fluid.

"Attraction is a property of the electric fluid, and this attraction has been discovered in the nervous fluid.

"We here see the greatest analogy between these fluids; nay, I may even add, the characters of their identity."

That there is a considerable analogy between some of the effects of the electric fluid and some of the phenomena of galvanism, we readily admit; but that "the characters of their identity" are anywhere to be found, we absolutely deny. In the above passage, Dr Valli considers it as certain that the nervous fluid is the cause of the phenomena discovered by Galvani. But it has never been demonstrated irrefragably, that any such thing as a nervous fluid exists, and still less that this is the same with the influence discovered by Galvani.

That bodies are, in general, conductors or non-conductors of galvanism, according as they are conductors or non-conductors of electricity, we believe to be true; but this rule is by no means without exception, as it certainly would be, if galvanism and electricity were the

same. There is an experiment of Dr Fowler's, which seems to shew that water is a more powerful conductor of galvanism than mercury; though the reverse is generally allowed as to electricity.

If the abdomen of a frog be filled with water, and a silver probe passed through it so as to touch the sciatic nerves, no contractions are produced; neither do they appear when the probe is touched above the surface of the water with a piece of zinc. But if the zinc be applied to the probe at the surface of the water, contractions are produced as vigorous as if both the metals touched the nerve. Here the water serves as a conducting medium between the nerves and the point where the metals touch each other: but if the abdomen be filled with mercury instead of water, no contractions are produced by applying the silver probe to the nerves, and touching the probe with the zinc at the surface of the mercury. We do not see how this experiment can be accounted for, except by allowing that water is a more powerful conductor of galvanism than mercury.

If this experiment should be thought inconclusive, we have the authority of M. Humboldt, and of the committee of the National Institute of France, for saying that there are substances which, though in an eminent manner conductors of electricity, yet interrupt the motions of galvanism. This is certainly sufficient to take away all weight from Dr Valli's two first reasons for considering these two fluids as the same, viz. that all conductors of electricity are likewise conductors of galvanism; and that all bodies which do not conduct the former are also non-conductors of the latter. These two are by far the most important of his reasons; and if they were true in their full extent, they would certainly shew a very striking analogy, though they would by no means deserve the appellation of "characters of identity."

As to the Doctor's two next propositions, which regard the effects of heat and cold in rendering bodies conductors or non-conductors, they are, in fact, only branches of the two first; and as we have seen that these are not universally true, we might admit that they are correct in this particular, without weakening our argument. For this reason we shall not consider them minutely; but we may observe that Dr Fowler's experiments shew that boiling water, and water cooled down to the freezing point, both conduct this influence as well as water at the ordinary temperature of the atmosphere. If any change in the conducting power takes place beyond these points, it may with greater probability be ascribed to the changes of form which the water undergoes, than to the increase or diminution of its temperature.

We confess ourselves perfectly ignorant of any data upon which Dr Valli could found a calculation, the result of which could shew that the velocity of the nervous fluid is the same with that of electricity. Suppose we should take it into our heads to assert that the velocity of galvanism is the same with that of light, we apprehend our author could not easily demonstrate the contrary. Neither, in all probability, would he consider this assertion of ours as a sufficient proof that galvanism and light are the same.

With regard to the next proposition, that "the obstacles which the nerves, under certain circumstances, oppose to electricity, they present likewise to the nervous fluid;" we may remark, that any obstacle which

destroys the functions of a nerve completely, will prevent the muscles which are supplied by that nerve from contracting upon the application of any stimulus whatever (G). It does not, however, by any means follow, that the passage of either the galvanic or the electric fluid is prevented. The nerves may still be very good conductors of both, though the muscle is deprived of all power of contracting. That there are obstacles, however, which the nerves, under certain circumstances, present to the passage of electricity, but which they do not under the same circumstances present to galvanism, we think abundantly demonstrated by Dr Valli's own experiments.

23
Inconsistent
with his
own expe-
riments,

“ I have frequently observed (says he) that the legs, of which the nerves had been tied at a certain distance from the muscles, did not feel the action of a certain quantity of artificial electricity, although they were violently convulsed by exciting that which was inherent and peculiar to them.” What then was the cause of the difference observed in these cases between the effects of galvanism and electricity? Was it, that the quantity or degree of the former exceeded that of the latter? Be it so.

Dr Valli informs us, that in his experiments, an electric charge which could flash through a thickness of air equal to .035 of an inch, produced no movement in the leg of a frog of which the crural nerve was tied, while the other leg, of which the nerve was left free, underwent considerable movements.

That the influence discovered by Galvani can pass through an exceeding thin plate of air, is certain, as it is transmitted from link to link of a chain, where no considerable force is used to bring the links into contact. Dr Robison's experiment, too, in which the flashes of light are distinctly observed before the rods of silver and zinc touch each other, is another proof of the same fact; and, if we be not deceived, the same thing takes place when a rod of silver thrust up the nostril is applied to a piece of zinc in contact with the tongue. But that it will only pass through an exceeding thin plate of air, any man may convince himself by an experiment first tried by Dr Fowler, which is easily repeated. If a stick of sealing-wax be coated with tinfoil, it will be found a very good conductor; but if, with a sharp pen-knife, an almost imperceptible division be made across the tinfoil, even this interruption of continuity in the conductor will be found sufficient effectually to bar the passage of galvanism.

We find, then, that a quantity of the electric fluid which can pass through a plate of air of the thickness of .035 of an inch, is obstructed by a ligature upon a nerve, while the galvanic influence passes readily along a nerve included in a ligature, but is obstructed completely by making an almost imperceptible division in a good conductor. The plate of air in this case surely is not near .035 of an inch in thickness. It results incontestably, from a comparison of these two experiments, that there is, between these two agents, some other difference besides the mere degree of intensity.

We come now to the last reason which our author

assigns for his belief that galvanism, or, as he chooses to call it, the *nervous fluid*, is the same with electricity. It will be found a very important one. That property by which bodies charged with the electric fluid attract or repel other bodies, according as they are in the same or the opposite state of electricity from themselves, is so striking, and at the same time so universal, that it has been very properly adopted as the measure of this fluid. If it were true, then, that the galvanic influence possessed the same properties of attraction and repulsion as the electric fluid, this circumstance would certainly increase the analogy between them very much. As we have already seen, however, that they differ in other essential points, even if it were true that they agreed in this, it could constitute no proof of their identity. But if, on the other hand, we should find that this assertion of our author is founded on error, and that the galvanic influence possesses in no degree whatever those properties of attraction and repulsion which have always been justly considered as essential characteristics of the electric fluid, we shall then be fully justified in asserting, that these two agents, however much they may resemble each other in some less important particulars, are in their nature totally distinct and unconnected.

Let us examine the proofs by which Dr Valli's assertion is supported. He tells us, that he observed the hairs of a mouse, attached to the nerves of frogs, by the tinfoil with which he surrounded them, alternately attracted and repelled by each other, whenever another metal was so applied as to excite contractions in the frogs. We are very far from meaning to insinuate that Dr Valli did not see, or think he saw, what he thus describes; but that the motion of the hairs must have arisen from some cause, different from that to which he ascribed it, cannot admit of a doubt; for hairs, in such a state of electricity as he supposes, never attract, but always repel each other.

24
And with
the know-
ledge of e-
lectricity.

Dr Fowler, who has paid particular attention to this part of his subject, has many times repeated this experiment, both in the manner described by Dr Valli and with every variation in the disposition of the hairs which he could devise: but whether they were placed on the metals, the nerves, or the muscles, or upon all, at the same time, he has never in any instance been able to observe them agitated in the slightest degree. He has made similar experiments upon a dog, and upon a large and lively skate, by disposing, in the same way that Valli did the hairs of a mouse, flakes of the finest flax, swan-down, and gold leaf: but although the contractions produced in the skate, by the contact of the metals, were so strong as to make the animal bound from the table, not the least appearance of electricity was indicated. He next suspended from a stick of glass, fixed in the ceiling of a close room, some threads, five feet in length, of the flax used in the former experiment; and brought some frogs recently killed, and insulated upon glass, as near to them as possible without touching: but the threads were in nowise affected by the contractions produced in the frogs.

In a very ingenious paper upon galvanism by Dr Wells,

(G) We do not here mean that contraction which muscles are susceptible of long after death, upon having their fibres mechanically irritated, which is produced by what physiologists have called the *vis insita*, and which is perfectly known to our cooks, as it was to their predecessors in the Roman kitchens, as the foundation of the art of crimping. We at present confine ourselves to contraction produced through the medium of the nerves.

25
Reasoning
of Dr Wells
on the
same sub-
ject,

Wells, which is published in the London Philosophical Transactions for 1795, that gentleman maintains the opinion, that the influence discovered by Galvani is electrical. He admits, that it is not attended with those appearances of attraction and repulsion which are held to be the tests of the presence of electricity; but he contends, that "neither ought signs of attraction and repulsion to be in this case presented on the supposition that the influence is electrical; since it is necessary, for the exhibition of such appearances, that bodies, after becoming electrical, should remain so during some sensible portion of time; it being well known, for example, that the passage of the charge of a Leyden phial, from one of its surfaces to the other, does not affect the most delicate electrometer, suspended from a wire, or other substance, which forms the communication between them."

26
Inconclu-
sive like-
wise.

That the charge of a Leyden phial does not, in passing along a wire, affect an electrometer, is certain; and it is equally true, that we have no means of applying an electrometer to a quantity of galvanism in a state of rest in a body. If this influence ever exists in such a state, we have no test by which we can discover its presence; and it is only from the effects which it produces *in transitu* that we know of its existence. But the electric fluid, in passing from link to link of a chain, sensibly affects an electrometer; and in Dr Fowler's experiment with the skate, for example, as more than one piece of metal is employed as an exciter, the fluid, in passing from one piece to another, should have affected the light substances which were placed upon them. This appears to us a sufficient answer to the objection started by Dr Wells: but the same objection having been lately made to us by a gentleman from whom we shall always receive every suggestion with uncommon deference, we thought it worth while to try the following experiment:

Three hours after a frog had been decapitated, it shewed strong signs of galvanic susceptibility. One of the sciatic nerves being coated with tin-foil in the usual manner, the leg was laid upon a plate of zinc. A gentleman was desired to lay hold of the nerve and its coating with the fingers of one hand, which had been previously dipped in water, while with the other hand, also wet, he held the end of a small brass chain about two inches in length. Another gentleman now took hold of the other end of the chain, and, with a silver probe, held in his other hand, touched the plate of zinc. The influence being thus made to pass through the chain, the leg contracted vigorously; but a very sensible electrometer, held so near to the chain as almost to touch it, was neither attracted nor repelled. In performing this experiment, it was necessary to have the hands wet, as the dry cuticle tends much to obstruct the passage of galvanism; but the utmost care was taken that the chain should be perfectly dry, otherwise the influence might have been transmitted by the moisture upon its surface without passing through the chain itself.

To avoid the possibility of this happening, the experiment was varied in the following manner: The frog's leg was laid upon a plate of zinc, and the nerve upon a plate of silver. A gentleman now took a silver probe, and one end of the brass chain in contact with it, in one hand; and in the other hand he held the other end of the chain in contact with a rod of zinc. He now touched the silver plate with the rod of silver, and the

zinc plate with the rod of zinc. As the influence was not now to be made to pass through his body, there was no necessity for his hands being wet; the whole excitatory arc was therefore made completely dry. In this way very strong contractions were excited in the leg, and still the electrometer was not affected in the smallest degree when brought near the chain.

It is proper to observe, that Dr Valli, in his assertion that attraction is a property of galvanism, does not rest entirely upon his own observation: a committee of the Academy of Sciences at Paris performed the following experiment along with him: "They placed a prepared frog in a vessel which contained the electrometer of M. Coulomb, charged negatively and positively by turns. In both cases, in exciting the animal in the common way, the ball of the electrometer was attracted." It appears to us that Dr Valli and the committee have been deceived by the friction produced by the motion of the animals under their experiments having excited so much electricity as to affect the electrometer. The first time we tried the experiment abovementioned with the brass chain, we were almost misled by a similar circumstance. Instead of an artificial electrometer, which we happened not to have at hand, we made use of a very long and slender human hair; and we found that it was strongly attracted by the chain. Upon an attentive examination, however, we found that this did not arise from the action of the influence passing thro' the chain, but from the state of the hair itself, which was so highly electrical as to be strongly attracted by every conducting substance which it approached. Upon substituting another hair, which shewed no mark of being either positively or negatively electrified, it was neither attracted nor repelled by the chain. From the above, or some similar circumstance, it is probable that Dr Valli's mistake has originated; but we are confident, that whoever will repeat the experiment with sufficient attention, will find the result precisely as we have described it.

Perhaps it may still be said, that although we have never been able to discover attraction and repulsion as properties of galvanism, this may arise from our not being able to accumulate this influence in sufficient quantity. To this reasoning, if reasoning it can be called, we oppose the following considerations, which state a dissimilarity in the phenomena of electricity and galvanism, that seems absolutely irreconcilable with the identity of the cause.

Nothing is more completely established in the science of electricity than this, that all those appearances which we call *attractions, repulsions, abstractions, and accumulation of electric fluid*, are precisely similar to what would be the appearances, if electricity were a fluid, whose particles repel each other, and attract the particles of other matter, according to a certain law (See ELECTRICITY, *Suppl.*). Of all those phenomena, the most remarkable is the accumulation of electric energy (to give it no more definite name), by means of thin idio-electrics, coated with non-electrics; such, namely, as are exhibited by the Leyden phial, the condenser, the doubler, &c.

If the phenomena of galvanism are produced by the passage of electric fluid from one extremity of the excitatory arc to the other, this passage will be regulated by the known laws of electricity. It may therefore be accumulated

27
Demonstration, that the phenomena of galvanism and of electricity result not from the same cause.

accumulated (*in transitu*) by means of an apparatus similar to the coated pane, or to the condenser. Professor Robison, with this view, made the following experiments :

1. He made a part of the conductor to his condenser, or collector of atmospheric electricity, consist of a long glass rod, on one side of which was fastened (with varnish) a very narrow slip of tinfoil; there was a fine point at one end of this rod, and a gold leaf electrometer at the other. This apparatus was insulated at one end of a room 19 feet long, having a window in the middle of each side. A small electric machine was placed at the other end. On a dry day, with a gentle breeze in a direction across the room, both windows were opened a little way, so that there was a continual stream of air across the room. The machine was worked; and after a short time had elapsed, the electrometer began to diverge, gradually opened, and at last struck the conducting slips on each side, and then collapsed, and again began to diverge. The windows were shut; and immediately, without working the machine, the electrometer diverged rapidly, and touched the sides of the phial every minute and half. This continued so long, that there seemed to be no end to it. The Professor now made a cut across the tinfoil with a very sharp knife; the electrometer now diverged very feebly, and $7\frac{1}{2}$ minutes elapsed before it touched the sides. He passed the knife a second time through the cut. This widened it (though scarcely sensible to the eye), because the knife had been blunted by the glass in the first operation. All divergency of the electrometer was now at an end; and although the machine was worked till the electric smell was sensible at the door to a person who happened to come in at this time, no tendency to divergence was observed. (*N. B.* the top of the electrometer had no conducting substance about it, except the slip of tinfoil).

The cut, being examined with a microscope furnished with a micrometer, was $\frac{3}{1000}$ th of an inch. It was now filled up, by binding over it another slip of tinfoil. A plate of talc, whose thickness did not exceed the 900th of an inch, was coated on one side in a circle of $1\frac{1}{2}$ inch diameter. The electrometer was removed, and the coated side of the talc was put into close contact with the slip of tinfoil on the glass rod. A stand of tin, whose top was a plate of $1\frac{1}{2}$ inch diameter, smeared over with mercury, was placed in contact with the other side of the talc, and they were pressed into very close and continuous contact.

The machine being now worked, the coated talc received a charge in about 5 minutes sufficient to give a very smart shock: and this was repeated with great regularity every five or six minutes. The windows were now thrown open, and the room cleared of its former contents of air, till none of those present could perceive any electric smell. The machine was now worked again. But after half an hour, only a very faint twitch was felt; but enough to shew that an ac-

cumulation was taking place. The windows were now half shut. After working the machine about five minutes, a faint twitch was obtained; after a quarter of an hour more, there was a moderate shock.

In this state of things, the apparatus was examined as a condenser, by first taking out the sharp point by an insulating handle, and then removing the tin stand. Examined in this way, it appeared plainly that, even when all the windows were open, the accumulation began almost as soon as the machine was worked. Nay, it was found, on another day equally favourable, that a plate of talc $\frac{1}{1000}$ or $\frac{1}{800}$ of an inch thick, took a charge, although a cut of $\frac{1}{1000}$ wide did not allow the electricity to fly across it. This is perfectly similar to all our experiments on coated glass. The thickness which admits an accumulation is almost incomparably greater than the distance to which a spark will fly, or a concussion is producible, in the same intensity of electricity.

2. The above described apparatus was insulated, and a wire connected with each end. To one wire was joined a thin plate of lac, coated on the side next the wire; and to the other a piece of moist leather covered with tin-foil. These plates were rubbed together by means of insulating handles. The plate of coated talc quickly took a charge.

The same plate of talc, and afterwards another plate not more than half as thick, was now made part of the excitatory arc, and sometimes part of the animal arc. Sometimes plates of varnish, incomparably thinner than either of these, were employed. But all Professor Robison's attempts to produce an accumulation of galvanic energy in this way were fruitless. The second form of the electrical experiment was adopted, as having a somewhat greater resemblance to the supposed procedure of galvanism; but the well-informed electrician will easily perceive, that the first form is far more delicate and decisive.

The internal procedure in the electric and galvanic convulsions is therefore so different, nay, opposite, that we cannot bring ourselves to think that the appearances are operations of the same agent (μ).

We have now gone over all the points of resemblance which, in Dr Valli's opinion, constitute the characters of the identity of galvanism and electricity. We think that, without going farther, we might safely rest our assertion, that these two agents are perfectly distinct and unconnected with each other. But there are several other circumstances which merit attention.

No electrical phenomenon can take place between two bodies, unless these bodies be in opposite states of electricity with regard to each other. Now, how are we to account for the accumulation of electricity in any body, or part of a body, surrounded on all hands by conducting substances? The experiments of Galvani succeed equally well, whether the subjects of them be insulated or surrounded by conductors; whether performed in the driest air or under water (1); whether, by

(μ) What if it were called *metallorgasm*, which translates exactly metallic irritation, or metallegerism, from *μεταλλον*, and *εγερσις excitatio*.

(1) Dr Fowler mentions an exception to this. "When the separated leg of a frog was held under water, and formed part of the circuit through which this influence had to pass in order to excite another leg, it never contracted; although it did, and strongly, when held above the surface." In this case it is plain, that the frog's leg

by means of an electrical machine, we charge the animal and the metals till every part of them strongly affect the electrometer, or whether we reverse the experiment and electrify them negatively, still no change is produced in the force or frequency of the actions excited by the application of the metals. Is there any electrical experiment which could continue to give the same result in such opposite circumstances? or is there any possibility of accounting for it consistently with the known laws of the electric fluid?

The writers on this subject who adopt the electric theory, instead of attempting to explain how the electric fluid can be condensed in a body surrounded by conducting substances, have recourse to the analogy of the gymnotus, torpedo, and other fishes of the same kind. Here, say they, we have in fact the electric fluid accumulated in such a situation, and there is no reasoning against facts. We answer, that these animals are all furnished with organs of a very peculiar structure, which may possibly be fitted for the purpose of such a condensation. Besides, we apprehend it has never been incontrovertibly proved that these singular animals derive their powers from the electric fluid. Without wishing to enter into this question, which is foreign to our present subject, we may remark that Mr Walsh discovered, that the shock of the torpedo would not pass through a small brass chain; a circumstance in which it differs remarkably both from electricity and from the influence discovered by Galvani.

It were worth while to try Professor Robison's methods of accumulation in the examination of the convulsions occasioned by the torpedo. The Professor suspects that the popular horror at the lamprey, and the accounts of cramps and pains produced by it, have their source in some similar powers of that animal.

Dr Valli's reasoning on this part of the subject is very curious. He takes it for granted that the gymnotus owes its influence to the electric fluid. Then, though the gymnotus gives shocks and emits sparks, while the torpedo only gives shocks without emitting sparks, he says it would be absurd to assert that the torpedo derives its influence from a cause different from the gymnotus. Again, though the influence discovered by Galvani neither gives shocks nor emits sparks, it would still be absurd to maintain that it is not the same as the electric fluid, and as the influence of the gymnotus and torpedo. To dissent from any part of this very logical deduction, he declares would be contrary to the laws of philosophising! *Risum teneatis?*

Afraid, probably, that his readers might be tempted to offend against these new laws, he proceeds to strengthen them by the analogy of animals and vegetables retaining an uniform temperature *in media*, warmer or colder than their own bodies; from which he argues that they may also have a power of accumulating electricity, and re-

taining it in a particular part, though their whole bodies are conductors. But the cases are in no respect similar. Neither animals nor vegetables accumulate caloric in any particular part of their bodies in preference to any other part. They have no power of retaining caloric in their bodies more strongly than any other bodies do; for if they are placed in a medium colder than themselves, they are continually imparting caloric to that medium. Neither is there the smallest proof, from any experiments yet published, that when placed in a medium warmer than themselves, they do not continually absorb caloric from it. The existence of a frigorific power in animals appears to us exceedingly problematical; but if it were proved to exist, it would by no means demonstrate that animals or vegetables have a faculty of declining to absorb caloric from bodies warmer than themselves. It is readily admitted, that animals and vegetables have a power, within certain limits, of preserving their temperature higher than that of the surrounding medium; nor is there any thing surprising in this, as the caloric, which they are continually receiving by the decomposition of oxygenous gas, is dissipated slowly. But if we should allow that animals have a similar faculty of generating the electric fluid; from the nature of that fluid it must be continually communicated, not only to every part of the bodies of the animals themselves, the whole of which are conductors, but to every conducting substance contiguous to them: and this must take place, not slowly, like the dissipation of caloric, but instantaneously, so as to render any sensible accumulation impossible.

Galvanism differs from electricity in nothing more remarkably than in the mode of its excitement and discharge. To produce the phenomena discovered by Galvani, no operation at all similar to the friction of an electric upon a conducting substance is necessary (κ). The nerves and muscles have only to be laid bare, and a communication formed between them by means of the excitatory arc, when the contractions immediately ensue. In the case of electricity, a single discharge having restored the equilibrium, no farther effects can be produced till this has been again destroyed by some means capable of producing a condensation in one quarter and a comparative rarefaction in another. The fact is very different with regard to galvanism; for with it the number of shocks which may be given appears to be infinite. Nay, they frequently become stronger in proportion as they have been longer continued: this influence differing extremely in this particular, too, from the electric fluid, which, besides being itself exhausted, never fails in a remarkable manner to exhaust the contractile power of the muscles.

The permanence of the effects of galvanism is still more striking in the experiments upon the organ of taste. When the metals are applied to the tongue, the effects, ²⁹ Difference in their mode of excitement,

leg had in fact formed no part of the circuit through which the influence passed; the influence had been transmitted by the water in which the leg was held.

(κ) It is true, as we have noticed above, that galvanic energy is sometimes communicated to a conducting substance by rubbing it upon some other substance; but this has no resemblance to the excitement of electricity by friction. The galvanic energy is communicated in this case to a *conducting* substance, and it succeeds as readily when both the bodies are of this class as when one of them is an idio-electric. But no electric phenomenon has ever been produced by the friction of two conducting bodies upon each other; one of them must be an idio-electric, and it is in this one that the excitement takes place. ³⁰ And in the duration of their effects.

sensation produced is not sudden and transient; but so long as the metals are in contact with the tongue and with each other, so long does the taste continue; and, after some time, it becomes insufferably disagreeable. M. Volta, who adopts the electric theory with various modifications, sensible of the permanence of the effect, in his curious experiments abovementioned supposes, that a stream of electricity passes from the tin cup to the liquor, from this to the tongue of the person making the experiment, then through his body, and returns through the water upon his hands to the cup; and thus he supposes the fluid to move perpetually in a circle. It is surely unnecessary for us to observe, that the supposition of a stream of electricity continually moving in a circle in this manner, is wholly inconsistent with the laws which appear in every case to regulate the motions of that fluid. The same observation applies to the manner in which he explains most of the other phenomena of galvanism.

The electric fluid cannot be put in motion but by destroying the equilibrium to which it perpetually tends; but whenever this is destroyed, all that is required to produce a discharge is, that a single conducting substance be placed between the two points in which it is unequally distributed. Here again there is a very wide distinction between this fluid and the influence discovered by Galvani. M. Volta divides all conductors of galvanism into two classes; 1st, Dry conductors, comprehending metals, pyrites, some other minerals, and charcoal; and, 2d, Moist conductors. He asserts, that it is absolutely necessary, in order to the production of the phenomena, that two conductors of the first class touch each other immediately on one hand, while at their other extremities they touch conductors of the second class. Whether this be admitted or not, we have already stated our opinion that the action of two different substances is absolutely necessary in order to excite contractions: and although it is contended by some writers that a single piece of metal has sometimes been found sufficient, yet even they must allow that, in by far the greater number of cases, it has been found necessary to make use of two metals, and that the effect is even heightened in general by employing three. In the whole science of electricity, we

do not know a single fact which bears the slightest analogy to this. Never in a single instance has it been found, that the effects of a Leyden phial have been increased by using a conductor formed of two or more metals in procuring the discharge.

Before leaving the subject of conductors, we may take notice of a very curious and important fact mentioned by Dr Valli. "Amongst men," says he, "there are some individuals who are good conductors, others who are less so; and some again who appear to be almost non-conductors. I was one day carrying on, with three of my friends, some experiments upon frogs. A frog was put in water, and we each by turn essayed its power. Two of us excited strong convulsions, the third only feeble ones, and the fourth none at all. This experiment was repeated frequently with the same result. This is not the only example I could adduce of the reality of this fact, but I do not think it necessary to dwell any longer upon it." We have met with one individual who is not sensible of any peculiar sensation when the metals are applied to his tongue. This seems in some measure to corroborate Dr Valli's observation. It is apprehended, however, that all men are equally good conductors of electricity.

There is still another very marked distinction between the effects of galvanism and electricity. No shock at all resembling that produced by the electric fluid has ever been felt by any person whose body was made a part of the chain conducting the galvanic influence, while a very small quantity of the electric fluid is immediately felt (L). In Dr Robison's experiment with the plates of zinc and silver in the cheeks, there is no doubt a convulsive twitch distinctly felt in the gums; but, as we have already observed, the sensation thus produced is quite different from that which is felt from an electric shock (M).

There is an experiment related by Dr Valli, which seems to shew that nothing like an electric shock is felt, even when this influence is transmitted through a nerve, so as to excite convulsions. Having laid bare the nerves of a fowl's wing, without cutting them, and without killing the fowl, upon applying the metals very smart movements were produced, but the animal remained perfectly tranquil. Nor was this owing to the fowl

(L) There is an exception to this rule which ought to be taken notice of. M. Cotugno informs us, that when he was one day employed in dissecting a live mouse, he received a sensible shock from the animal. But as neither he nor any other person has ever been similarly affected in any other instance, it seems pretty certain that he was deceived into the belief of a shock from the sensation produced by the struggles of the animal he dissected.

(M) "No one (says M. Humboldt) can speak more decidedly on this subject than myself, having made several experiments on my own person, the seat of which, in some instances, was the socket of a tooth which I had caused to be extracted; in others, certain wounds which I made in my hand; and in others, the excoriations produced by four blistering plasters." The following is the result of these painful experiments. The galvanic irritation is always painful, and the more so in proportion as the irritated part is more injured and the time of irritation more prolonged. The first strokes are felt but slightly; the five or six following are much more sensible, and even scarcely to be endured, until the irritated nerve becomes insensible from continued stimulus. The sensation does not at all resemble that which is caused by the electric commotion and the electric bath; it is a peculiar kind of pain, which is neither sharp, pungent, penetrating, nor by intermissions, like that which is caused by the electric fluid. We may distinguish a violent stroke, a regular pressure, accompanied by an unintermitting glow, which is incomparably more active when the wound is covered with a plate of silver and irritated by a rod of zinc, than when the plate of zinc is placed on the wound, and the silver pincers are used to establish the communication.

fowl being in a state of insensibility; for when the nerves were pricked or irritated it screamed violently. But all animals shew signs of great uneasiness from an electric shock.

In general, it must be confessed, that animals under experiments of this kind seem restless and uneasy. The great distinction of which we speak at present, consists in this, that the electric fluid produces a shock and uneasy sensation when any part of the body is introduced into the conducting chain; while the influence discovered by Galvani, on the contrary, when merely transmitted through the body in this manner, gives no shock, nor any sensation whatever, inasmuch that we are not sensible of its passage. If this influence be made to act directly on a nerve, there is, no doubt, some kind of irritation produced, as appears from the effect of the metals upon the tongue, the eye, and other nervous parts; but still this action bears no analogy to that of the electric fluid. As the application of the metals to the organs of sense, produces in each organ the peculiar sensation for which it is constructed, as taste in the tongue, light in the eye, &c. so when nerves intended merely for muscular motion are subjected to the action of galvanism, the effect produced is motion in the muscles on which they are distributed.

If this view of the matter be just, it will explain why no shock is felt when the human body is made a part of the conducting chain. In that case the influence does not, in all probability, act directly upon any nerve; and we see that this influence possesses no power, like the electric fluid, of producing a convulsive shock, when merely passed through any part of the body; but it has this peculiar property, when passed directly through a nerve, it excites that nerve to perform the function for which it was intended by nature. To this it will no doubt be objected, that contractions may be excited in different parts of a frog without any division being made in its skin; and here it may be supposed that the influence is not made to pass directly through a nerve. But it ought to be recollected that the skin of these animals is abundantly supplied with nerves, whose trunks communicate at different places with those which supply the muscles; and that the contractions are always strong and easily excited, in proportion as they are applied near to the course of any of the nerves which go to the muscles. But though we had no doubt that the influence might be transmitted through the bodies of these animals, as well as through the human body, without any contractions being produced, we have thought it worth while to ascertain the fact by the following experiment.

A frog was prepared in the usual manner by coating its sciatic nerve with tinfoil, and laying the leg upon a plate of zinc. Another frog, in a very vigorous state, had its fore legs and chest attached to a rod of silver, and its posterior extremities to a rod of zinc. The silver rod was applied to the tinfoil and nerve of the prepared frog, and the zinc rod to the plate of zinc upon which the leg was laid. Immediately very strong contractions took place in the leg; but no motion, nor the slightest mark of uneasiness, appeared in the other frog through the body of which the influence must have passed. It is necessary in this experiment to dry the body of the frog which is to serve as a conductor very carefully, otherwise the influence

might be transmitted by the water upon its surface without passing through its body.

There is an experiment mentioned by Dr Fowler, which shews a striking difference between electricity and galvanism. It was instituted with a view to ascertain the effects of the latter upon the blood-vessels. The Doctor relates it as follows: "Having laid bare and separated from surrounding parts and from each other, the crural artery and nerve in the thigh of a full grown frog, I cut out the whole of the nerve between the pelvis and the knee: I then insinuated beneath the artery a thin plate of sealing wax, spread upon paper, and broad enough to keep a large portion of the artery completely apart from the rest of the thigh. The blood still continued to flow through the whole course of the artery in an undiminished stream. The artery, thus partially insulated, was touched with silver and zinc, which were then brought into contact with each other; but no contraction whatever was produced in any muscle of the limb. This experiment was frequently repeated upon several different frogs, both in whom the nerve was, and in whom it was not divided. The result was uniformly the same. But vivid contractions were produced in the whole limb when an electric spark, or even a full stream of the aura was passed into the artery."

Before taking leave of this branch of our subject, it may be proper to take notice of one fact, which may be thought to militate against the doctrine we have endeavoured to establish. It is said that a frog, exhausted and brought near to a charged electrophorus, has been found to resume its susceptibility. We think this fact may be accounted for without admitting any connection between galvanism and electricity, merely by supposing that the irritability of the muscles, which had been exhausted, was restored by the application of a moderate stimulus, (the electric fluid), of a kind different from those by which it had been exhausted. Such of our readers as are acquainted with the writings of modern physiologists on the subject of muscular irritability, will know that facts of this kind are very common. Thus it has been found by M. Humboldt, that the oxygenated muriatic acid has often restored irritability. To this explanation it will no doubt be objected, that the application of other stimuli, as alcohol and a solution of potash, instead of restoring, totally destroy the susceptibility of galvanism. Suspecting, that although these substances in a concentrated state destroy the susceptibility, yet that when sufficiently diluted, they might be found to have the opposite effect, we tried the following experiment, which confirmed our conjecture.

A frog, 57 hours after it had been decapitated, had ceased for above an hour to be capable of excitement by the application of the metals in any way that could be devised. A few drops of alcohol being diluted with about a tea-spoonful of water, the nerve and the muscles which had been laid bare, as well as the whole skin of the animal, were wet with it. Upon the application of an excitatory arc, composed of four pieces, gold, zinc, silver, and tinfoil, a few very slight contractions of the toes were distinctly observed. After this, no means that we could think of produced the smallest excitement. Alcohol was now applied in a more concentrated state, but without any effect. The same

four pieces of metal which produced the contractions of the toes, had been used before the diluted alcohol was applied, but without effect. We have not tried the application of potash much diluted.

From what has been said, we think we are fully warranted in saying, that although some of the phenomena discovered by Galvani bear a striking resemblance to some of those produced by the electric fluid; yet there are others, and these not the least important, which differ so widely from any effects which have ever been seen to arise from that fluid, that they must derive their origin from some other cause. Our readers may probably think that we have dedicated too much time to this question; but as we conceive it to be the most important point which can be discussed on this subject, we thought it worth while to consider it at some length; and we were the more convinced of the necessity of doing so, from this consideration, that there are still some writers of high authority who maintain the hypothesis, that galvanism and electricity are the same.

³²
The galvanic influence probably foreign from animals.

The next question that occurs to us with regard to the nature of galvanism is, whether or not it depends upon any law of animal life? To us it appears rather more probable, that the influence which incites the muscles of animals to contract in the experiments of Galvani, is something quite foreign to the animals themselves; as much so as the electric fluid of the Leyden phial is to the animal which receives a shock from it, in both cases the body of the animal acting as a mere conductor. Upon this question, however, we confess that we have neither facts nor arguments to adduce sufficient to warrant our drawing any certain conclusion. It will doubtless be asked, if this influence be something foreign to the bodies of animals, why do we never find it acting anywhere but in their bodies? why is it not, like the electric fluid, capable of being made evident to the senses by its effects upon inanimate matter? The only answer which we are in a condition to give to this question is, that it may very possibly be capable of producing important effects upon inanimate matter, nay, these effects may be the subject of our daily observation; but for want of our being sufficiently acquainted with galvanism to point out the relation between these effects and their cause, the effects themselves are either not explained at all, or ascribed perhaps to some other power, with which they have no connection. In like manner, the electric fluid has doubtless been producing most important effects from the beginning of time; but, prior to the discovery of that fluid, these were either not explained at all, or considered as originating from some cause which, in fact, had no share in their production.

The great difficulty is to obtain some test by which we may detect the galvanic influence when actually present in inanimate matter. Hitherto we have no such test; nor should we know that such an influence exists, but for the effects which it produces upon the bodies of animals through the medium of their nerves. If we had any means of ascertaining its existence, either in a separate state, or conjoined with inanimate matter, the science would make a rapid progress, as it would be easy to diversify experiments so as to discover its nature and effects. To detect it in a separate state is, in all probability, impossible; but that the zeal and inge-

nity of philosophers will one day be able to discover some test of its presence in inanimate matter, there seems no reason to doubt.

We have made many experiments with a view to discover such a test, but hitherto without the smallest success. In the trials we have already made, our views have been chiefly confined to the discovery of some chemical effects of this influence upon inanimate matter. M. Volta and other writers, having considered the sensation produced by it upon the tongue as similar to that occasioned by acids, we were not without hopes that it would be found to resemble that class of substances in some of its other properties. We have therefore transmitted it through liquids tinged with the most delicate vegetable colours; but no change in these colours has been effected by the transmission of many galvanic shocks. We have also tried, in the same way, alkaline liquors, without any effect. We next dissolved in water different neutral salts, and other compound bodies, of which the parts are held together by the weakest affinities; but no change has been observed to be produced in them by the transmission of this influence. Our want of success, however, shall not deter us from continuing our efforts; we shall vary the nature of our experiments in every way that shall occur to us as likely to be attended with advantage; and if we should ultimately fail, we trust that others will be more fortunate. Every new fact which is discovered upon the subject tends to facilitate this investigation, by furnishing us with new guides to direct the course of our experiments.

Dr Fowler is of opinion, that this influence, whatever it may be, is not derived from the metals alone, but that the animals at least contribute to its production, as well as indicate its presence; and he seems to have been led to adopt this theory chiefly from two considerations, neither of which appears to us to have much weight. They are the following: The necessity of a communication between the metals and the muscles, as well as between the metals and the nerves; and the observation, that animals have a more complete controul over its effects than one would expect them to have over an influence wholly external to them. But the communication between the metals and the muscles may be necessary to the contraction of the latter, tho' not to the production of galvanism; which, however, for want of any obvious effect, is not observed. That animals have some controul over the effects of galvanism upon themselves, may be very true; but this circumstance does not appear to us capable of proving any thing, as they have a controul over the effects of other stimuli in the same way. Thus, an animal of any resolution can bear, without betraying any uneasy sensation, a blow which, inflicted unexpectedly, would have produced a convulsive start. The will does not in any degree controul the effects produced by galvanism upon our senses of taste, seeing &c.; that is, the sensations are produced, though we may have resolution not to betray them. But, says Dr Fowler, the will is not able to controul the effects of electricity, when the electricity is otherwise sufficiently strong to excite muscles to contraction. This argument may tend to shew, that galvanism differs from electricity; but as it must be admitted, that we can resist the contractions naturally produced by the application of other foreign stimuli, it by no means proves that animals have any power of preventing

³³
Dr Fowler hesitates on this point.

preventing the excitement or transmission of galvanism. Besides, though we cannot prevent an involuntary contraction of our muscles from taking place when an electric shock of considerable strength is passed through them, yet any man may with his hand draw sparks from the prime conductor of an electric machine without shrinking, though even these sparks would, if he were off his guard, produce a convulsive start.

If the galvanic influence existed ready formed in the muscles or nerves of animals, the only thing requisite to the production of the contractions would be to make a communication between the nerves and muscles, by means of any single substance capable of conducting this influence; as water, for example: but the reverse is known to be true. It may be said, however, that, although there is no proof that any influence naturally resides in the nerves or muscles capable of producing the effects mentioned by M. Galvani, these substances may still, by some power, independent of the properties they possess in common with dead matter, contribute to the excitement of the influence, which is so well known to exist in them after a certain application of metals. Upon this part of the subject, the observations of Dr Wells will be found to merit considerable attention.

“It is known (says that gentleman), that if a muscle and its nerve be covered with two pieces of the same metal, no motion will take place upon connecting those pieces by means of one or more different metals. After making this experiment one day, I accidentally applied the metal I had used as the connector, and which I still held in one hand, to the coating of the muscle only, while with the other hand I touched the similar coating of the nerve, and was surprised to find that the muscle was immediately thrown into contraction. Having produced motions in this way sufficiently often to place the fact beyond doubt, I next began to consider its relations to other facts formerly known. I very soon perceived, that the immediate exciting cause of these motions could not be derived from the action of the metals upon the muscle and nerve to which they were applied; otherwise it must have been admitted, that my body and a metal formed together a better conductor of the exciting influence than a metal alone; the contrary of which I had known, from many experiments, to be the case. The only source, therefore, to which it could possibly be referred, was the action of the metals upon my own body. It then occurred to me, that a proper opportunity now offered itself of determining whether animals contribute to the production of this influence by means of any other property than their moisture. With this view I employed various moist substances, in which there could be no suspicion of life to constitute, with one or more metals, different from that of the coatings of the muscle and nerve, a connecting medium between these coatings, and found that they produced the same effect as my body. A single drop of water was even sufficient for this purpose; though, in general, the greater the quantity of the moisture which was used, the more readily and powerfully were contractions of the muscle excited. But if the mutual operation of metals and moisture be fully adequate to the excitement of an influence capable of occasioning muscles to contract, it follows, as an immediate consequence, that

animals act by their moisture alone in giving origin to the same influence in M. Galvani's experiments, unless we are to admit more causes of an effect than what are sufficient for its production.” We do not quote the above reasoning as perfectly conclusive, for it by no means appears to us to be so; but it certainly gives some probability to the opinion, that galvanism is, as M. Volta supposes, the result of the action of two dry conductors, which touch each other immediately on one hand, while at their other extremities they touch conductors of what he calls the second class, (that is, moisture, for all the conductors of the second class contain water), and that the bodies of animals act merely as moisture.

One of M. Humboldt's experiments related above, appears to us to strengthen the conclusion, that the influence discovered by Galvani is something perfectly foreign to the bodies of animals. Can it be supposed that any substance which naturally resides in our bodies, should, in a few seconds after it is put in motion, convert the simple serous discharge of a blister into a dark coloured fluid, of a nature so acrid as to irritate and violently inflame the skin wherever it touches it? We do not say that this is impossible, for we are too little acquainted with the laws of secretion to say with certainty what may, or what may not, produce such a change; but we know no similar alteration produced, *in a few seconds*, by a mere change of action in the vessels themselves.

We shall not undertake to determine the nature of ³⁵the cause which produces such astonishing effects. We think it is certainly not the electric fluid, and probably something which resides or is formed in the excitatory arc; but we consider our knowledge of galvanism as still in its infancy, and our stock of facts as infinitely too small to admit of our forming a just theory on the subject. Fortunately, however, the discovery of Galvani has attracted so much the attention of philosophers in every part of Europe, that new facts may be expected to come to light every day; and we hope the time is not very distant, when these may be so classed, as to entitle the subject to be ranked among the sciences. See TORPEDO in this *Suppl.*

WHILE this article was in the press, we were favoured by a friend with an account of some German dissertations on the subject, which we are obliged to insert in this irregular manner.

Mr Creve, surgeon in Wurtzburg, had an opportunity of observing the galvanic irritation on the leg of a boy, which had been amputated far above the knee in the hospital of that city. Immediately after the amputation, Mr Creve laid bare the crural nerve (kniekehlnerven), and surrounded it with a slip of tinfoil. He touched at once the tinfoil and the nerve with a French crownpiece. In that instant the most violent convulsions took place in the leg both above and below the knee. The remainder of the thighbone bent with force toward the calf; the foot was more bent than extended. All these motions were made with much force and rapidity. None were produced when the tinfoil was taken away, or when a steel pincer was used in place of a piece of silver, or when the tin or silver was covered with blood: but they were renew-

ed when these obstacles were removed. These phenomena continued till 38 minutes after the amputation, when the limb became cold.

Dr Christophher Heinrich Pfaff (*in Dissertatione de Electricitate Animalis*, Stutgardt, 1793: see also Gren's *Journal der Physik*, T. viii. p. 196, &c.) has classed the phenomena in a very orderly and perspicuous manner; and the result of the numerous experiments made by himself and others, corresponds very nearly with our inferences in the preceding pages.

I. *Phenomena of muscular contraction.*

The general form of his experiments is the same with that which we have placed at the beginning of this article; but the following varieties were observed:

The nerve being coated with tinfoil, it was always observed that the contractions were stronger when the silver first touched the muscle, and then the coating. If it touched the coating first, the effects were always, and very sensibly, weaker.

They were still stronger when the silver did not touch the muscle at all, but only the nerve and its coating.

When the contractions were weaker at the beginning, they also ceased sooner.

No contraction ensued from touching the coating only, or the nerve only, or the muscle only, with the silver.

Continuing the contact did not occasion any repetition of the contractions, except in some cases, where the silver was drawn along different parts of the coating, while its other end remained in contact with the nerve.

The contractions took place only in the muscles to which the nerve led.

Their strength and duration were greater when the surfaces of contact were greater, and when the two metals touched each other in points or sharp edges.

A ligature, with a silk thread below the coating (that is, between the coating and the muscle, or part of the nerve touched by the silver), prevented all contraction; but not if the ligature was between the coating and the brain. If the nerve was cut through below the coating, and the parts separated a quarter of an inch, no contraction followed by touching the coating and the nerve or muscle: but it took place, if the parts were brought into contact; or even if a piece of any other nerve was put between the parts.

If a considerable part of a bared nerve was insulated and coated, partly with tinfoil and partly with silver, contractions were produced in the muscle to which it led whenever the two metals were brought into contact.

If one crural nerve be coated with tin, and the other with silver, contractions are produced in both legs by bringing the metals into contact.

If the nerve be dry under the coating, or when the silver touches it, or in both places, we have no contractions; but they begin as soon as we moisten the nerve.

Dr Pfaff infers from these phenomena, that the nerve alone is subject to the irritation produced by the two metals.

If the prepared frog be immersed in water, so that the coating touches the water, contractions are produced by touching the coating above water with the silver, while another part of the silver touches the

nerve, or the muscle, or even dips pretty deep in the water.

No such thing happens in oil; or, at best, the contractions are very slight.

Dr Pfaff could not produce contractions without employing two metals, or a metal and charcoal.

A very thin covering of muscular flesh on the nerve did not altogether prevent the contractions, and in many cases did not sensibly diminish them.

If a piece of silver be laid on the muscles of the breast or belly, and be brought into contact with the tin-coating on the lumbar region, only the muscles of the breast or belly are affected, but not those of the legs.

Dr Pfaff says, that the involuntary muscles are not affected by galvanism; and refers for convincing proofs to a dissertation by Dr Ludwig, shewing that the heart is not furnished with nerves, (*Scriptor. neurolog. minor. select.* vol. 2.).

II. *Irritation of the Organs of Sense.*

Here Dr Pfaff's dissertation contains nothing remarkable.

III. *Conjectures as to the Cause.*

Dr Pfaff uses the same arguments that we have employed to refute the opinion of a similarity between the animal organs and the Leyden phial, and the opinion that electricity is the agent. He mentions the opinion of those who maintain that the agent is a fluid put into motion by means of its relation to the metals only, in their action on each other, and who consider the animal as merely serving as a conductor; and also serving, by its irritability, to give us the information of the presence of such a fluid, in the same manner as another kind of irritation, somewhat analogous to it, indicates the presence and agency of the electric fluid. It may therefore be called the METALLIC IRRITATION; a term which will sufficiently distinguish it.

But Dr Pfaff seems rather to think that the agent resides in the animal, and that the metals are the conductors (See a dissertation, entitled, *Further Contributions to the Knowledge of Animal Electricity*, in Gren's *Journal der Physik*, T. viii. p. 377.). This fluid he conceives to be intimately blended with the *principle of life*; nay, perhaps, to be the same. He mentions a thought of Professor Kielmayer, "that it may resemble the magnetic fluid in its manner of acting, giving connection to the distant particles of a nerve, as we observe a magnet give an instantaneous connection to each of a parcel of iron filings; all of which it would arrange in a certain precise manner, if they were sufficiently moveable, by giving momentary polarity to each." This somewhat resembles Newton's hypothetical whim read to the Royal Society, describing what may be done by means of an æther (See *Birche's History of the Royal Society*).

But all this is vague conjecture, and merits little attention. This will be better bestowed on an observation of M. Humboldt of Jena, "that a bit of fresh morelle (the *Helvella mitra* of Linnæus) may be substituted for a bit of nerve in the animal arc in these experiments." This is the only vegetable substance yet discovered to have this property. If the nerve be laid on the morelle, we have only to touch the morelle with the zinc, and the muscular contractions immediately follow.

GARDECAUT.

Gardecaut,
Garden.

GARDECAUT, or **GUARD DU CORD**, is a watch, is that which stops the fufee when wound up, and for that end is driven up by the fpring. Some call it Guard-cock; others Guard du Gnt.

GARDEN (Francis), better known to the public by the title of *Lord Gardenstone*, was born at Edinburgh June 24th, in the year 1721. His father was Alexander Garden of Troup; an opulent landholder in Aberdeenshire; his mother was Jane, daughter of Sir Francis Grant of Cullen, S.C.I.

After paffing through the ufual course of liberal education at the fchool and the univerfity, he betook himfelf to the ftudy of law for his profefion. In the year 1744 he was admitted a member of the Faculty of Advocates, and called to the Scottifh bar.

In his practice as an advocate he foon began to be diftinguifhed, by a ftrong, native rectitude of underftanding; by that vivacity of apprehenfion and imagination which is commonly denominated *Genius*; by manly candour in argument, often more perfuafive than fubtlety and fophiftical artifice; by powers which, with diligence, might eafily attain to the higheft eminence of the profefion. But the fame ftrength, openness, and ardour of mind, which diftinguifhed him fo advantageoufly among the pleaders at the bar, tended to give him a fondnefs for the gay enjoyments of convivial intercourfe, which was unfavourable to his progrefs in juridical erudition. Shining in the focial and convivial circle, he became lefs follicitoufly ambitious than he might otherwife have been, of the character of an eloquent advocate, or of a profound and learned lawyer. The vivacity of his genius was averfe from a ftere and plodding ftudy, while it was captivated by the fascinations of polite learning and of the fine arts. Nor did he always efcape thofe exceffes in the purfuit of pleafure into which the temptations of opening life are apt occafionally to feducer the moft liberal and ingenuous youth. But his cheerful conviviality, his wit, humour, tafte, good-nature, and benevolence of heart, rendered him the delight of all his acquaintance. He became his Majesty's Solicitor July 3d, 1764.

At length the worth of his character, and his abilities as a lawyer, recommended him to the office of a Judge in the Courts of Seffion and Jufticiary, the fupreme judicature, civil and criminal, for Scotland. His place in the Court of Seffion he continued to occupy till his death; but had, fome years before, refigned the office of a Commiffioner of Jufticiary, and in recompence got a penfion of 200l. per annum. Clear difcernment, ftrong good fenfe, confcientious honefty, and amiable benevolence, remarkably diftinguifhed all his opinions and conduct as a judge.

We not unfrequently fee the gay young men of the prefent age, to turn, as they advance towards middle life, from the headlong purfuit of pleafure to a fordid and contracted selfishnefs, which excludes even thofe few good qualities that feemed to accompany their firft thoughtlefs days. Their life is divided between fenfuality and that anxious *inhumane* avarice and ambition whose ultimate object is, to provide gratifications to fenfuality and pride. The kindling light of rectitude, and the firft fparks of generous humanity, are extinguifhed in their breafte as foon as thofe ebullitions of youthful paffion and inexperience are over, by which the ufeful efficiency of their early good qualities was

prevented. Hardly have they become tolerably well acquainted with mankind, when the milk of human kindnefs is turned into gall and venom in their hearts.

Garden.

It was far otherwife with Lord Gardenstone. As he advanced in years, humanity, tafte, public fpirit, became ftill more and more eminently the predominant principles in his mind.—He pitied the condition of the peafantry, deprefsed rather by their ignorance of the moft fkilful modes of labour, and by their remotenefs from the fphere of improvement, than by any tyranny or extortion of their landlords. He admired, protected, and cultivated the polite arts. He was the ardent votary of political liberty, and friendly to every thing that promifed a feafible amelioration of public economy, and the principles of government.

In the year 1762 he purchafed the eftate of Johnfton, in the county of Kincardine. Within a few years after he began to attempt a plan of the moft liberal improvement of the value of this eftate, by an extenfion of the village of Laurencekirk, adjoining. He offered leafes of fmall farms, and of ground for building upon, which were to laft for the term of one hundred years; and of which the conditions were extremely inviting to the labourers and tradefmen of the furrrounding country. Thefe offers were eagerly liftened to. More defirous to make the attempt beneficial to the country than to derive profit from it to himfelf, he was induced, within a few years, to reduce his ground-rents to one-half of the original rate.—Weavers, joiners, fhoemakers, and other artifans in a confiderable number, reforted to fettle in the rifing village. His Lordfhip's earneftnefs for the fuccefs of his project, and to promote the profperity of the good people whom he had received under his protection, led him to engage in feveral undertakings; by the failure of which he incurred confiderable loffes. Projects of a printfield, and of manufactures of linen and of ftockings, attempted with fanguine hopes in the new village, and chiefly at his Lordfhip's rifk and expence, mifgave in fuch a manner as might well have finally difgufted a man of lefs fteady and ardent philanthropy with every fuch engagement. But the village ftill continued to advance. It grew up under his Lordfhip's eye, and was the favourite object of his care. In the year 1779 he procured it to be erected into a burgh of barony; having a magiftracy, an annual fair, and a weekly market. He provided in it a good inn for the reception of travellers; and with an uncommon attention to the entertainment of the guefts who might refort to it, furnifhed this inn with a library of books for their amufement. He invited an artift for drawing, from the continent, to fettle at Laurencekirk. He had the pleafure of feeing a confiderable linen manufacture at length fixed in it. A bleachfield was alfo eftablifhed as a natural counterpart to the linen manufacture. Before his Lordfhip's death, he faw his plan of improving the condition of the labourers, by the formation of a new village at Laurencekirk, crowned with fuccefs beyond his moft fanguine hopes. He has acknowledged, with an amiable franknefs, in a memoir concerning this village, "That he had tried, in fome meafure, a variety of the pleafures which mankind purfue; but never relifhed any fo much as the pleafure arifing from the progrefs of his village."

In the year 1785, upon the death of his elder brother,

ther,

Garden. ther, Alexander Garden of Troup, M. P. for Aberdeenshire, Lord Gardenstone succeeded to the possession of the family estates, which were very considerable. Until this time his Lordship's income had never been more than adequate to the liberal expence into which his rank, and the generosity of his nature, unavoidably led him. But the addition of a fortune of about three thousand pounds a-year to his former revenue, gave him the power of performing many acts of beneficence with which he could not before gratify his good heart. It was happy, likewise, that his succession to this ample income, at a period when the vigour of his constitution was rapidly yielding to the infirmities of old age, enabled him to seek relief, by a partial cessation from business, by travel, and by other means, which could not have been easily compatible with the previous state of his fortune.

In the month of Sept. 1786, he set out from London for Dover, and passed over into France. After visiting Paris, he proceeded to Provence, and spent the winter months in the genial climate of Hieres. In the spring of 1787 he returned northwards, visiting Geneva, Switzerland, the Netherlands, and the Dutch provinces, and passing through Germany into Italy. With a fond curiosity, attentive alike to the wonders of nature, to the noble monuments of the arts, and to the awful remains of ancient grandeur, with which Italy abounds, he visited all its great cities, and surveyed almost every remarkable and famous scene that it exhibits.

His first object, in these travels, was to obtain the restoration of his declining health by the influence of a milder climate, by gentle, continued, and varied exercise; by that pleasing exhilaration of the temper and spirits, which is the best medicine to health, and is most successfully produced by frequent change of place, and of the objects of attention. But the curiosities of nature and art, in those countries through which he travelled, could not fail to attract, in a powerful manner, the curiosity of a mind cultivated and ingenious as his. He, whose breast glowed with the most ardent philanthropy, could not view the varied works and manners of a diversity of nations of his fellow men, without being deeply interested by all those circumstances which might appear to mark their fortunes as happy or wretched. He eagerly collected specimens of the spars, the shells, the strata of rocks, and the veins of metals, in the several countries through which he passed. He amassed also cameos, medals, and paintings. He enquired into science, literature, and local institutions. He wrote down his observations, from time to time; not indeed with the minute care of a pedant, or the ostentatious labour of a man travelling with a design to publish an account of his travels, but simply to aid memory and imagination in the future remembrance of objects useful or agreeable.

After an absence of about three years he returned to his native country. The last years were spent in the discharge of the duties of his office as a judge; in social intercourse with his friends, among whom was the venerable Lord Monboddo, and others of the most respectable characters that our country has to boast of; in the performance of a thousand generous offices of benevolence and humanity; in cherishing those fine arts, of which he was an eminent admirer and judge; and above all, in promoting the comfort, and encouraging

the industry of his dependants, and in lending his aid to every rational attempt at the improvement of public economy and public virtue.

St Bernard's Well, in the neighbourhood of Edinburgh, had been, long since, distinguished for the medicinal virtues of its waters. But various circumstances had also concurred of late to throw it into neglect. Yet its waters being strongly mineralized by a sulphurated hydrogenous gas, were, by this means, unquestionably qualified to operate, with highly beneficial effects, in the cure of various diseases. The qualities of this mineral water falling under Lord Gardenstone's notice, he was induced to purchase the property of the well, to direct it to be cleared from surrounding obstacles, which contaminated the virtues of the water, or made it inaccessible; to erect a beautiful and commodious edifice over it; and to appoint proper persons to distribute the water, for a very trivial compensation, to the public. The well lies at a distance from Edinburgh, which is very convenient for a summer morning's walk. Within the few years which have passed since Lord Gardenstone's benevolent care brought it into notice, it has attracted many of the inhabitants of that city to visit in the mornings of spring and summer. And, undoubtedly, the agreeable exercise to which they have thus been allured, and the salutary effects of the water, have contributed, in no mean degree, to dispel disease, and to confirm, or re-establish health. Such monuments are worthy to preserve the memory of a patriotic and a good man!

As an amusement for the last two or three years of his life, when his increasing infirmities precluded him from more active exercise, and from mingling so frequently in the society of his friends as was agreeable to his social and convivial temper, he bethought himself of revising some of the *jeux d'esprit*, and light fugitive pieces, in which he had indulged the gaiety of his fancy in his earlier days; and a small volume of poems was published, in which the best pieces are, upon good authority, ascribed to Lord Gardenstone. He revised also the memorandums which he had made upon his travels, and permitted them to be sent to press. The two former volumes were published one after another while his Lordship was yet alive; the third after his death. They met with a very favourable reception in the world, and were honoured with the high approbation of the most respectable writers of periodical criticism. They convey much agreeable information, and bespeak an elegant, enlightened, and amiable mind. The last volume is filled chiefly with memorandums of his Lordship's travels in Italy; and contains many interesting criticisms upon some of the noblest productions of the fine arts of painting and sculpture.

His Lordship's health had long been declining; and he died a bachelor on the 22d of July 1793, lamented by his relations and friends, by his tenants and humble dependants, and by all true patriots and good men to whom his merits and virtues were known.

Such is the account of Lord Gardenstone's life, which was prefixed to the third volume of his travelling memorandums; and though it was no doubt an effusion of fond friendship, we believe that the praise which it bestows on his Lordship is not much exaggerated. In the latter years of his life, it must indeed be confessed, that he contracted intimacies with men unworthy

Gas
-||
Geocentric.

worthy of his regard; and that his attachment to liberty made him form expectations from the French revolution, which even the events which he saw ought to have repressed. But his mind was by that time weakened by disease; and it would be very unjust to balance the imprudencies of one or two years against the meritorious actions of a whole life. Besides his travelling memorandums and his poems, his Lordship published *A Letter to the Inhabitants of Laurencekirk*, the most valuable, in our opinion, of all his publications; for it contains perhaps the most salutary advices which were ever offered to the inhabitants of a manufacturing town, for the regulation of their conduct towards each other. That the people of Laurencekirk have followed these advices, it would give us pleasure to learn on good authority.

GAS. See that article, *Encycl.* and **CHEMISTRY-Index** in this *Supplement*. We have introduced the word here, to notice some experiments made by Professor Jacquin of Vienna, at the desire of Dr Chladni, on the different gases as the vehicle of sounds. A glass bell was furnished with a metallic stopper cemented to a neck at the top; and in the bore of this cock, within the glass, a small flute or pewter (etain) about six inches in length was fixed. The glass being then placed on the shelf of the pneumatic vessel, and filled with any particular kind of gas, a bladder also filled with the same gas, and provided with a cock, was adapted to the external aperture of the cock belonging to the bell-glass. In this disposition of the apparatus, the flute was made to sound by gently pressing the bladder. Comparative experiments were made with atmospheric air, oxygen, hydrogen, carbonic acid, and nitrous gas. The intensity of the sound did not vary; but when compared with that produced by atmospheric air, the oxygen gas gave a sound half a tone lower; azotic gas, prepared by different methods, constantly gave a sound half a tone lower; hydrogen gas gave nine or eleven tones higher; carbonic acid gas gave one-third lower, and nitrous gas also very nearly a third lower. A mixture of oxygen gas and azot, in the proportions of the atmospheric air, afforded the tone of this last; that is to say, it was half a tone higher than each of the component parts alone. When the two gases were not uniformly mixed, the sound was abominably harsh. Chladni intends to give a fuller account of these interesting experiments.—*Journal de Physique*, Vol. IV. N. S. p. 57.

GAZONS, in fortification, turfs, or pieces of fresh earth covered with grass, cut in form of a wedge, about a foot long, and half a foot thick, to line or face the outside of works made of earth, to keep them up, and prevent their mouldering.

GEOCENTRIC PLACE OF A PLANET, is the place where it appears to us from the earth; or it is a point in the ecliptic, to which a planet, seen from the earth, is referred.

GEOCENTRIC Latitude of a Planet, is its latitude as seen from the earth, or the inclination of a line connecting the planet and the earth to the plane of the earth's (or true) ecliptic: Or it is the angle which the said line (connecting the planet and the earth) makes with a line drawn to meet a perpendicular let fall from the planet to the plane of the ecliptic.

GEOCENTRIC Longitude of a Planet, is the distance measured on the ecliptic, in the order of the signs,

between the geocentric place and the first point of Geometrical, Georgium.

GEOMETRICAL METHOD OF THE ANCIENTS. The ancients established the higher parts of their geometry on the same principles as the elements of that science, by demonstrations of the same kind: and they were careful not to suppose any thing done, till by a previous problem they had shewn that it could be done by actually performing it. Much less did they suppose any thing to be done that cannot be conceived; such as a line or series to be actually continued to infinity, or a magnitude diminished till it become infinitely less than what it is. The elements into which they resolved magnitudes were finite, and such as might be conceived to be real. Unbounded liberties have of late been introduced; by which geometry, which ought to be perfectly clear, is filled with mysteries.

GEOMETRICAL Solution of a problem, is when the problem is directly resolved according to the strict rules and principles of geometry, and by lines that are truly geometrical. This expression is used in contradistinction to an arithmetical, or a mechanical, or instrumental solution, the problem being resolved only by a ruler and compasses.

The same term is likewise used in opposition to all indirect and inadequate kinds of solutions, as by approximation, infinite series, &c. So we have no geometrical way of finding the quadrature of the circle, the duplicature of the cube, or two mean proportionals, though there are mechanical ways, and others, by infinite series, &c.

GEORGIUM SIDUS (see *ASTRONOMY-Index, Encycl.*) has no fewer than six satellites revolving round it, all discovered by Dr Herschel. Of the two which he first discovered, one was found to revolve in 8 days 17 h. 1 m. 17 sec. at the distance of 33" from its primary; and the other in 13 d. 11 h. 5 m. 1,5 sec. at the distance of 44",23. The planes of their orbits form such large angles with that of the planet itself, and consequently of the ecliptic, as to be almost perpendicular to it. To this remarkable departure from the analogy of the old planets, another still more singular has been lately announced. They move in a retrograde direction! The new satellites revolve as follows, the periodical times being inferred from their greatest elongations: The interior satellite in 5 d. 21 h. 25 m. at the distance of 25",5. A satellite intermediate between the two old ones in 10 d. 23 h. 4 m. at the distance of 38",57. The nearest exterior satellite at about double the distance of the farthest old one, and consequently its periodical time 38 d. 1 h. 49 m. And the most distant satellite full four times as far from its primary as the old second satellite. Whence it will take at least 107 d. 16 h. 40 m. to complete its revolution. Whether the motions of these four be direct or retrograde, is, we suppose, not yet determined.

From some observations of the Doctor, with an excellent seven-foot telescope, certain appearances, resembling that of two rings surrounding the planet, and crossing each other at right angles, were seen on several different days. They were not altered in position by turning the speculum in its cell; but (says Mr Nicholson) there is little doubt that they were optical deceptions, because they kept their position with respect to the tube, after the relative position of the parallel had been

Gerard. been much changed by the earth's rotation, and because they did not appear with larger telescopes applied during the course of ten years. The disk of the Georgium Sidus is flattened. It therefore revolves with considerable rapidity on its axis. From the very faint light of the satellites, they are observed to disappear in those parts of their orbits which bring them apparently nearest the planet. This does not arise from an atmosphere; for the effect is the same, whether the satellite be within or beyond the planet.

GERARD (Alexander, D. D.), was the eldest son of the reverend Gilbert Gerard minister of Chapel Garioch, in the county of Aberdeen. He was born on the 22d of February 1728, and received the first rudiments of his education at the parish school of Foveran in the same county.

It may perhaps be proper to inform our English readers, that in every parish in Scotland there is a school where, for very small fees, the youth of the parish are not only taught to read the English language, to write, and to perform the elementary operations of arithmetic, but are also instructed in the Greek and Latin languages. Of these schools, many of the masters were, about sixty years ago, eminent for classical learning; and it seems that Mr Forbes, the master of the school of Foveran, possessed such fame as a teacher, that Mr Gerard judged it more expedient to commit his son to his care than to have him educated at the school of his own parish, and under his own immediate inspection. The attainments which that son afterwards made in literature, evince that his judgment was correct, and that the schoolmaster of Foveran deserved the fame which he enjoyed.

Young Gerard, however, did not remain long at Foveran. His father died when he was but ten years old; and his mother removing soon afterwards with her family to Aberdeen, he was of course put to the grammar school in that city: but so solid was the foundation which had been already laid, that in two years time he was deemed fit for the university, and was accordingly entered a student in Marischal college. Such rapid progress supplies the place of that testimony which we have not been able to procure, respecting his early attachment to literature.

After completing the usual academical course of four years in the study of Greek, Latin, mathematics, and philosophy, he was admitted to the degree of master of arts; and immediately afterwards commenced the study of theology, which he prosecuted in the universities of Aberdeen and Edinburgh. In 1748, when he had little more than completed his 20th year, he was licensed to preach in the church of Scotland, and two years afterwards was chosen assistant to Mr David Fordyce professor of philosophy in the Marischal college and university of Aberdeen. In this capacity he performed the duties of the absent professor till the 7th of July 1752, when he was appointed successor to Mr Fordyce, who had been drowned on the coast of Holland, as has been already related in the Encyclopædia.

At that period it was the practice in the Marischal college, as it continued to be in the King's, for the same professor to carry forward a class of students for three successive years through all the different branches of philosophy which were taught in the college. These were, LOGIC, ONTOLOGY, PNEUMATICS, MORALS,

POLITICS, and NATURAL PHILOSOPHY; and Mr Gerard carried one class through this extensive course. MATHEMATICS and the GREEK language were taught by separate professors.

About the year 1754, a very material alteration was made in the order of teaching philosophy in the university of Aberdeen; and in the Marischal college each professor was restricted to one department of science. The principal and professors in that college, justly observing that the public is interested in every thing which relates to education, thought it incumbent upon them to lay before that public the reasons which had determined them to deviate from the arrangement which they had hitherto observed; and they employed Professor Gerard to draw up these reasons. This task he performed in a small pamphlet, which, being printed by the appointment of the college, appears to have given very general satisfaction.

This, indeed, it could hardly fail to do; for the judicious author points out very clearly the inconveniences of the old, and the advantages of the new plan of academical study. Having observed that the philosophy which had so long kept possession of the schools, consisted, in a great measure, of verbal subtleties and theories ill-grounded, though ingeniously devised, he proceeds to contrast it with the philosophy of Bacon and Locke, and to show of how little value the former is when compared with the latter. He then enters on a brief examination of the scholastic logic, and proves, to the conviction of every impartial judge, that the art of syllogising, though a proper enough introduction to a philosophy which was built on general principles, either taken for granted, or founded on very narrow and inadequate observation, is by no means fitted to assist the mind in the cultivation of that science which is deduced by induction from particular facts. "The only basis of philosophy (says he) is now acknowledged to be an accurate and extensive history of nature, exhibiting an exact view of the various phenomena, for which philosophy is to account, and on which it is to found its reasonings. This being the reformed state of philosophy, great inconveniences must be found in prosecuting the scholastic order of the sciences. The student must make a transition at once from words and languages to philosophy, without being previously introduced to the knowledge of facts, the sole foundation of, and preparation for it; he must be hurried at the first into the most abstruse, difficult, and subtle parts of it; he must be put upon examining the nature, foundation, and different kinds of evidence and reasoning, before he is acquainted with any specimens of these kinds by which they may be illustrated. And in proportion as philosophy is more improved, and more thoroughly reformed, these inconveniences must become more sensible.

"The view of these (continues he) induced the masters of the Marischal college to think of altering the hitherto received order; and after the most mature deliberation, made them at last resolve, that their students should, after being instructed in languages and classical learning, be made acquainted with the elements of history, natural and civil, of geography and chronology, accompanied with the elements of mathematics; that they should then proceed to natural philosophy; and, last of all, to morals, politics, logic, and metaphysics."

In vindicating this arrangement, he labours with great

Gerard. great earnestness, and we think with complete success, to shew the propriety of making logic the last branch of academical study. "All sciences (says he), all departments of knowledge whatever, must be premised as a ground-work to genuine logic. History has one kind of evidence, mathematics another, natural philosophy one still different, the philosophy of human nature another distinct from all these; the subordinate branches of these several parts have still minuter peculiarities in the evidence appropriated to them. An unprejudiced mind will in each of these be convinced by that species of argument which is peculiar to it, though it does not reflect *how* it comes to be convinced. By being conversant in *them*, one is prepared for the study of *logic*; for *they* supply him with a fund of materials; in *them* the different kinds of evidence and argument are exemplified; from *them* only those illustrations can be taken, without which *its* rules and precepts must be unintelligible.

"All just conclusions concerning the works of nature must be founded on an induction of particulars. And as in *natural philosophy* these particulars are supplied by observations and experiments on *natural bodies*; so in *logic*, the particulars, of which an induction must be made, are to be learned only from the body of *arts and sciences*. These are the subjects on which observations must be made, in order to lay down rules for investigating and proving the truths of which they are made; just as the genuine performances of any art are what must be considered and observed in laying down the rules of that art. No solid precept can be formed in logic, except by examining arts and sciences, and attending to the method of reasoning used in them, and to the evidence that accompanies it. In proportion as they are cultivated, and no farther, logic may be improved. And what is true of the invention of logic, is true likewise of the study of it. It can be understood no farther, than the several sciences which it reviews and criticises are previously understood. Accordingly we find, that all the systems of logic which have not been compiled from a careful review and examination of the several sciences, consist more of ingenious subtleties than of useful precepts assisting to the mind in the various parts of knowledge. And when logic has been learned before the other sciences, the substantial parts of it have been scarce attended to, or made any use of, in the prosecution of them; nor so much as understood, but in as far as the mind was gradually opened, and brought to recollect them in its progress through the sciences.

"Logic is precisely the same to *philosophy* that works of criticism are to *poetry*. The rules of criticism are formed by an accurate scrutiny and examination of the best works of poetry. To one who had never read a poem, these rules would be obscure and useless; he could not comprehend them, far less would he be able to form a judgment of their justness, and of the reasons on which they are founded. If one peruses the best poetical performances, he will acquire some degree of taste, though he has never professedly studied the rules of criticism; and he will, at the same time, lay in materials, and obtain a stock of examples, which may render these rules intelligible to him, and enable him to judge whether they are just or not. And by afterwards studying these rules, he improves, refines,

and corrects his taste, perceives the principles on which he has founded all his judgments, though he did not in the mean time think of them, and gains additional security against his judging wrong. This may illustrate what has been said of the place which logic ought to hold among the sciences. The observations made in it, both concerning the methods of invention and of probation, are founded on, and deduced from, the several sciences in which these methods are used. Neither the observations themselves, nor the reasons on which they are built, can be fully comprehended by one absolutely ignorant of these sciences. In studying the particular sciences, reason will spontaneously exert itself: if the proper and natural method of reasoning is used, the mind will, by the native force of its faculties, perceive the evidence, and be convinced by it, though it does not reflect *how* this comes to pass, nor explicitly consider according to what general rules the understanding is exerted. By afterwards studying these rules, one will be farther fitted for prosecuting the several sciences; the knowledge of the grounds and laws of evidence will give him the security of *reflection*, against employing wrong methods of proof and improper kinds of evidence, additional to that of *instinct* and *natural genius*. And thus logic will greatly contribute to improvement in knowledge; and more so, when it is used as a *review* of the method taken in the prosecution of science, of the foundations gone upon, and of the general rules that have been observed, than when it is applied as an *introduction* to the elements of science; for in the former case, its rules can be perfectly understood, sufficiently illustrated, and put in practice as they are learned, which in the latter is quite impossible."

Having thus vindicated the new arrangement with respect to the place which it assigns to the study of logic, he proceeds to inquire in what order the other sciences should succeed each other. "Ethics (says he) or moral philosophy is founded as well as logic on pneumatics, and must therefore come after it. The constitution of man, and his several active powers, must be explained, before his business, his duty, and his happiness, can be discovered. Jurisprudence and politics, taking a more complex view of man than morals, by considering his various states, as well as his nature and powers, cannot, with any propriety, be introduced till morals have first been studied.

"It only remains then to determine whether natural philosophy or pneumatology ought, in the order of teaching, to have the preference. And many considerations seem to require that the former should be studied first. If it were not, pneumatology would be too far disjointed from the practical sciences founded on it; one of which, logic, ought, as we have seen, to be taught last of all. Besides, we ought always to begin with the easiest and most obvious subjects, and to proceed gradually to the most difficult; and in order to this, we ought to comply as much as possible with the natural openings and progress of the human mind. Now it is evident, that the mind receives first of all impressions and ideas of those sensible things with which it is surrounded. It is not till after it has exercised its faculties about them that it reflects on its own operations, or acquires perceptions of them. We are from our earliest infancy accustomed to observe external things, though often transiently and inattentively; they

Gerard. lie always in our view, they force themselves upon us, and we cannot avoid regarding them more or less. But we seldom attend to the operations of our minds in our earlier years; it is late before we acquire distinct notions of them, or can easily and readily make them the objects of our contemplation. Farther, external sensation, by which bodies are perceived, is a more palpable kind of evidence than internal, from which all our knowledge of spirits is derived; it strikes and affects us more. The philosophy of spirits, as well as that of bodies, is founded solely on experiments and observations; but in the latter it is much easier to make these than in the former: we can put *bodies* in any situation that we please, and observe at leisure their effects on one another: but the phenomena of the *mind* are of a less constant nature; we must catch them in an instant, and be content to glean them up, by observing their effects as they accidentally discover themselves in the several circumstances of life. The reasonings also by which conclusions are deduced concerning mind are of a more abstruse and difficult nature than those employed in the science of bodies; the ideas about which they are conversant are apter to be confounded with one another, and are with greater difficulty kept distinct. On all these accounts, natural philosophy must be to young minds easier than pneumatology, and consequently should be taught first."

For this long digression, if such it shall be deemed, we are persuaded that those who retain any attachment to the place where their minds were first imbued with the principles of science, will think no apology requisite, when they are informed, that the plan of education, which is here so ably defended, was about the same period adopted by both colleges in the university of Aberdeen; that the writer of this article had his own education in the King's college; and that in the prosperity of that college he still feels himself deeply interested. Let it be remembered, too, that the publication from which this extract has been made, furnishes a proof of professor Gerard's abilities, and of the estimation in which he was held by his colleagues at a very early period of life; and then surely the digression will not be thought impertinent.

He was now professor of moral philosophy and logic, and of these sciences alone: but though his *plan of education in the Marischal College* shews the order in which his lectures were arranged, we have not been able to learn on what foundation he built his system of ethics. As Hutcheson's Moral Philosophy was then much read and admired, it will not detract from Mr Gerard's merits to suppose, that, with his predecessor Mr Fordyce, he was an advocate for the *moral sense* of that author; for there are but three or four foundations on which a system of ethics can be raised; and it may be doubted whether there be one of them which is not as old as the age of Plato. It would indeed be ridiculous in any modern (A) to aim at giving a *new*

Gerard. foundation to moral virtue; for virtue must have been practised upon some steady principle from the earliest period of human society; and the most eminent professor will find sufficient room for the display of all his learning and ingenuity in illustrating the principle which his own judgment has led him to adopt.

Of this professor Gerard was fully sensible; and whilst he was conscientiously discharging his duty to his pupils, he neglected no opportunity of improving himself. He was member of a literary society at Aberdeen, of which the respectability will not be questioned, when it is known that it consisted of such men as the late Doctors Blackwel, Gregory, Reid, and Campbell, with Dr Beattie, and many others of perhaps equal talents, though not known to the world as authors (B). This society met regularly during the winter, we believe once every fortnight; the members communicated their sentiments with the utmost freedom; every novel opinion was sure to be canvassed on all sides with impartiality; the understandings of the members were thus mutually whetted; and hence originated Reid's *Inquiry into the Human Mind*, Gregory's *Comparative View*, Gerard's *Essay on Genius*, Beattie's *Essay on Truth*, and Campbell's *Philosophy of Rhetoric*.

On the 5th of September 1759, Mr Gerard was ordained a minister of the Church of Scotland; on the 11th of June 1760, he was appointed professor of divinity in the Marischal College, and minister of the Grayfriars church in Aberdeen; and at the same time, as we suppose, created doctor in divinity.

On the 18th of June 1771 he resigned his professorship in Marischal College, together with his church-living, and was preferred to the theological chair in the university of King's College, then become vacant by the death of professor Lumiden. In that station he continued, prosecuting his studies, beloved by his colleagues, and revered by his pupils, till his birth-day 1795; when, having just completed his 67th year, he died without a groan. His death was occasioned by a scirrhus tumor, which began to appear on his face in the year 1794, but without confining him to the house, or, except for a very few weeks, interrupting his usual pursuits. It impaired, however, his health, and gradually undermined his constitution. Of this he was very soon sensible; but he saw his dissolution approaching with the utmost composure and resignation, and preserved to all about him so much of that equanimity and placidness of temper which had marked the whole course of his life, that of him may truly be said,

Multis illi multos annos precantibus
Diri carcinomatis veneno contabuit,
Nexibusque vitæ paulatim resolutis,
E terris, meliora sperans, emigravit.

Were we to hazard an opinion of Dr Gerard's intellectual powers, from having attentively perused his works,

(A) The friends of Mr Godwin, who affect to call his Political Justice the *new* philosophy, will, of course, think this a rash assertion; but were it worth while, it would be no very difficult task to produce, from the atheistical writers of antient Greece, something similar even to his wildest paradoxes. Dr Gerard was too well acquainted with the subject, and too warm a friend to genuine virtue, to pretend to *novelty* in moral science.

(B) Such as Professor Thomas Gordon, who read lectures in the King's College for 63 or 64 years, and whose learning was equalled only by his virtues.

Gerard. works, we would say that he possessed great rectitude of judgment, rather than any remarkable vigour of mind; that he was capable, by intense study, of becoming master of almost any subject, though perhaps he had not the imagination requisite for making discoveries in science; and that his attainments were solid rather than brilliant. What he knew, he knew thoroughly; but to us his knowledge seems to have been the reward of labour.

By one, to whom he was well known, and who himself stands high in the republic of letters*, we are assured that he had improved his memory to such a degree, that, in little more than an hour, he could get by heart any sermon of ordinary length; though far from availing himself of this talent, as many would have done, he composed with care all the sermons that he preached. In early life he made it a rule not to study after supper; and from that rule he never deviated, but amused himself after that time, either with the conversation of his family, or with any light reading that came in his way; and he was generally in bed by half past eleven. He seems not to have approved of early more than of late study; for though, for a few years, when as professor of philosophy he had various sciences to teach, he rose regularly, during winter, at five in the morning, he discontinued that practice as soon as he had it in his power, and did not enter upon serious study till after breakfast, generally about ten o'clock. He was indeed very laborious through the day, and could with difficulty be persuaded to take any bodily exercise; but being remarkably temperate in eating and drinking, he enjoyed very good health, which was only occasionally interrupted by those stomach complaints, to which men of sedentary lives are often subject.

The fruits of this incessant study were, besides the lectures which he read to his different classes, 1st, *An Essay on Taste*, to which, in 1756, was adjudged the gold medal by the Philosophical Society of Edinburgh (See SOCIETIES, *Encycl.*), which had proposed taste as the subject for a prize. Of this essay there has been a second, and a third edition; of which the last, which was published in 1780, is considerably enlarged and improved. 2^d, *Dissertations on the Genius and Evidences of Christianity*, published in 1766. 3^d, *An Essay on Genius*, published in 1774. 4th, Two volumes of *Sermons*; of which the first was published in 1780, and the second in 1782. 5th, A part of his theological course, entitled *The Pastoral Care*, which was published in 1799 by his son Dr Gilbert Gerard, who succeeded him as professor of divinity in the King's college and university of Aberdeen. Besides these works Dr Gerard published many single sermons, which were preached on occasional subjects.

Of this amiable and respectable instructor of youth, we have been favoured with the following character, drawn by a man of talents and virtue †, who was first his pupil and afterwards his friend; and though it made part of a funeral sermon, we believe that, by those who were most intimately acquainted with Dr Gerard, the panegyric which it contains will not be deemed extravagant.

“ In domestic life, his conduct was amiable and exemplary. He possessed, in a high degree, that kindness of heart and affability of manner which interested him

at all times in the happiness of his dependants, preferred good humour in his house, and endeared him to his family. He knew how to check improprieties without harshness, and when and how to indulge without impairing his authority. His natural good sense, steadiness, and prudence, prevented him from being thrown into confusion by the adverse incidents of life; and enabled him, in pressing emergencies, to adopt wise measures, and to administer salutary counsel. His tender sympathy soothed the troubled hour of sorrow; his rational and friendly advice guided his family through the perplexities of life, and he feelingly rejoiced in all their innocent enjoyments. His attachments were not confined to his family or his relatives; he was susceptible of warm friendship. In selecting the objects of it he was cautious, always preferring those whose merits entitled them to confidence and regard. His attachment, slowly formed, was not to be shaken by every oblique insinuation, or by every idle report to the prejudice of his friend. Steady in his professions of regard, he was capable of considerable and disinterested exertions to serve those whom he really esteemed. To his judicious advice they had ready access; and his best efforts to promote their good they could always command. As a member of society, his house was ever the seat of hospitality, and his door was always open to the stranger. In entertaining his friends, he equally avoided the extravagance and ostentation which did not become his character or suit his fortune, and the rigid economy which marks the conduct of those who give with a reluctant and sparing hand. He neither anxiously courted, nor affectedly shunned learned conversation. While he never obtruded upon company subjects which, by the display of superior knowledge or abilities, were calculated to gratify his own vanity at the expense of hurting others, he always studied, as far as propriety would admit, to adapt his conversation to the temper and inclinations of his associates. To please the young, and to promote their harmless festivity, was ever his delight; with cheerfulness he descended to their trivial amusements, and in his presence they felt no restraints but those which virtue and decency impose. Though he often left for a little studies in which he was keenly engaged, to enjoy the conversation of a friend, he never suffered his love of society, one of his strongest passions, to induce him to sacrifice any important literary pursuit, or to neglect any necessary business.

“ As a clergyman, the office which he held for several years in Marischal college rendered it his duty to be a daily preacher, and gave him a seat in the ecclesiastical courts. But the unavoidable labour of preparing lectures for his theological pupils, did not prevent his unremitting attention to his public exhibitions in the pulpit. These were marked by that distinctness of arrangement, that justness of reasoning, and that accuracy of composition, which effectually secured the approbation of the ablest judges; while by their plainness and simplicity, they failed not of promoting the edification of the meanest capacities. To the low arts of acquiring popularity he never stooped: But his prudence, his good sense, his exemplary conduct, and his ministerial diligence, established his respectability and usefulness, and procured him the full confidence and esteem of his colleagues. Possessing more than ordi-

* Dr Beattie.

† The Rev. Skene Ogilvie, Old Aberdeen.

Gerard.

dinary excellence, envy never led him to depreciate the merits of other preachers. Though one of the best of judges, he was always one of the most candid hearers. When by his translation to the university of King's college he was released from the labour of constant preaching, far from shewing any aversion to discharge the most public ministerial duties, he was always obedient to presbyterial appointments; and while health and strength remained, willing to oblige his clerical friends by appearing in their pulpits. Nor in private life did he ever lose sight of the character of a clergyman. Having in a publication ably defended its respectability, in opposition to the scoffs and sneers and sophisms of modern sceptics; he considered it as his honour, in his life and conversation, to display its dignity and importance; and to shew that the gravity of a Christian pastor is perfectly consistent with the good breeding of a gentleman, and with the cheerfulness, affability, and ease of an agreeable companion.

"As a man of letters, his attainments were far above those at which the generality of students arrive. In his literary pursuits, he had all the advantages of a judgment uncommonly clear and distinct; aided, from his earliest years, by the most indefatigable and persevering study. The well-earned reputation with which, before he was promoted to the theological chair, he taught in Marischal college different sciences, inconceivably proves that his powers, not confined to one subject, justly entitled him to eminence in several branches of literature. His publications, several of which have been translated into other languages, promise fair to extend his fame, and to hand it down to generations yet unborn; and his unremitting labours promised still a farther contribution to the general stock of learning.

"As a professor of divinity, he will be long and gratefully remembered by his numerous pupils. This was his peculiar department, and in this he shone. Possessing large stores of theological knowledge, he was judicious in selecting his subjects, happy and successful in his manner of communicating instruction. He had the merit of introducing a new, and in many respects a better plan of theological education, than those on which it had been formerly conducted. Liberal, but not loose, in his sentiments, his great aim was, not to impose by his authority upon his pupils any favourite system of opinions; but to impress them with a sense of the importance of the ministerial office, to teach them the proper manner of discharging all its duties, and to enable them, by the knowledge of Scripture, to form a just and impartial judgment on controverted subjects. Solicitous for their improvement, he was ever ready to encourage rising merit by his warmest approbation; and reluctant to damp even unsuccessful efforts of genius by deserved censure. Having a constant eye to what is practically useful, rather than to unedifying specula-

tion, he enjoined no duty which he was unwilling to exemplify in his own conduct. Hence that strict regard to the ministerial character which he uniformly displayed, and hence his uncommon punctuality in attending the public ordinances of religion."

Germination.

GERMINATION, among botanists, is a very interesting subject, on which the late discoveries in chemistry have thrown much light since the article GERMINATION was published in the *Encyclopædia*. In the year 1793, Mr Humboldt discovered that simple metallic substances are unfavourable to the germination of plants, and that metallic oxides favour it in proportion to their degree of oxidation. This discovery induced him to search for a substance with which oxygen might be so weakly combined as to be easily separated, and he made choice of oxygenated muriatic acid gas mixed with water. Cresses (*lepidium sativum*) in the oxygenated muriatic acid shewed germs at the end of six hours, and in common water at the end of 32 hours. The action of the first fluid on the vegetable fibres is announced by an enormous quantity of air bubbles which cover the seeds, a phenomenon not exhibited by water till at the end of from 30 to 45 minutes. These experiments, announced in Humboldt's *Flora Subterranea Fribergensis*, and in his Aphorisms on the chemical physiology of Plants, have been repeated by others (A). They were made at a temperature of from 12 to 15 Reaumur. In the summer of 1796, Humboldt began a new series of experiments, and found that by joining the stimulus of caloric to that of oxygen he was enabled still more to accelerate the progress of vegetation. He took the seeds of garden cresses (*lepidium sativum*), peas (*pisum sativum*), French beans (*phaseolis vulgaris*), garden lettuce (*lactuca sativa*), mignonette (*reseda odorata*); equal quantities of which were thrown into pure water and the oxygenated muriatic acid at a temperature of 88° F. Cresses exhibited germs in three hours in the oxygenated muriatic acid, while none were seen in water till the end of 26 hours. In the muriatic, nitric (B), or sulphuric acid, pure or mixed with water, there was no germ at all: the oxygen seemed there to be too intimately united with bases of azot or sulphur, to be disengaged by the affinities presented by the fibres of the vegetable. The author announces, that his discoveries may one day be of great benefit in the cultivation of plants. His experiments have been repeated with great industry and zeal by several distinguished philosophers. Professor Pohl at Dresden caused to germinate in oxygenated muriatic acid the seed of a new kind of *euphorbia* taken from Bocconi's collection of dried plants, 110 or 120 years old. Jacquin and Vander Schott at Vienna threw into oxygenated muriatic acid all the old seeds which had been kept 20 or 30 years at the botanical garden, every attempt to produce vegetation in which had

(A) See Ussler's Fragments of Phytology, Plenck's Physiology, Willdenow's Dendrology, and *Dictionnaire de Physique* par Gehlér.

(B) The nitric acid, however, diluted with a great deal of water, accelerates germination also, according to the experiments of Candolle, a young naturalist, who has applied with great success to vegetable physiology. This phenomena is the more interesting, as chemistry affords other analogies of the oxygenated muriatic acid and the nitric acid. Professor Pfafs at Kiel, by pursuing Humboldt's experiments, has found that frogs suffocated in oxygenated muriatic acid gas increase in irritability, while those which perish in carbonic acid gas are less sensible of galvanism.

Gesche,
Gheysfi-
quas.

had been fruitless, and the greater part of them were stimulated with success. Even the hardest seeds yielded to this agent. Among those which germinated were the yellow bonduc or nickar tree (*guilandina bonduc*), the pigeon cytifer or pigeon pea (*cytifer cajan*), the *dodonea angustifolia*, the climbing mimosa (*mimosca scandens*), and new kinds of the *homea*.—There are now shewn at Vienna very valuable plants which are entirely owing to the oxygenated muriatic acid, and which are at present from five to eight inches in height. Humboldt caused to germinate the *clusia rosea*, the seeds of which had been brought from the Bahama islands by Boose, and which before had resisted every effort to make them vegetate. For this purpose he employed a new process, which seems likely to be much easier for gardeners who have not an opportunity of procuring oxygenated muriatic acid: He formed a paste by mixing the seeds with the black oxide of manganese, and then poured over it the muriatic acid diluted with water. Three cubic inches of water were mixed with half a cubic inch of the muriatic acid. The vessel which contains this mixture must be covered, but not closely shut; else it might readily burst. At the temperature of 95° the muriatic acid becomes strongly oxidated; the oxygenated muriatic gas which is disengaged passes through the seeds; and it is during this passage that irritation of the vegetable fibres takes place.—*Philosophical Magazine*.

GESCHE EL AUBE, or GIR GIR, a species of grass growing plentifully near *Ras el Feel* on the borders of Abyssinia. It begins, says Mr Bruce, to shoot in the end of April, when it first feels the humidity of the air. It advances then speedily to its full height, which is about 3 feet 4 inches. It is ripe in the beginning of May, and decays, if not destroyed by fire, very soon afterwards.

The leaf is long, pointed, narrow, and of a feeble texture. The stock from which it shoots produces leaves in great abundance, which soon turn yellow and fall to the ground. The goats, the only cattle these miserable people have, are very fond of it, and for it abandon all other food while it is within their reach. On the leaves of some plants our author saw a very small glutinous juice, like to what we see upon the leaves of the lime or the plane, but in much less quantity; this is of the taste of sugar.

From the root of the branch arises a number of stalks, sometimes two, but never, as far as he had seen, more than three. The flower and seed are defended by a wonderful perfection and quantity of small parts. The head, when in its maturity, is of a purplish brown.

This species of grass was one of the acquisitions of our author's travels. It was not before known in Europe, nor when he published his book had the seed produced a plant any where but in the garden of the French king.

GHEYSSIQUAS, a nation of Hottentots which inhabits a district of South Africa bordering on the country of Caffraria. M. Vaillant visited a horde of this people at no great distance from Orange river, as he was returning from his last African excursion to the Cape, and was shewn by them a chain of mountains to the east, which extending to a distance was lost in the north, and which, inhabited by their principal tribes, separated them from the Caffies, or at least from the

Briquas and Breimas, whom they consider as tribes of Caffres.

Gheysfi-
quas.

With respect to such characteristics as are not original and derived from nature, as the form of their dress, weapons, instruments of music, fondness for hunting and dancing, and the like, the Gheyssequas do not differ from the surrounding nations, except in having adopted a particular colour for their ornaments. All the ornaments of the Gheyssequas are white, and composed of the bones of a sheep's leg or foot, to which they give a dazzling whiteness by processes peculiar to themselves. Thus, as they fabricate their own necklaces and other articles of luxury, and have no occasion to purchase the materials, they have no dependence on the colonies with respect to trade, except for a few necessary articles, which they want in common with other savages. Accordingly this nation is less known and less visited than any other.

The women are well made, lively, and always ready to laugh or dance: yet, with all the gaiety of their disposition, they have the reservedness of manners to which polished nations give the names of modesty and decorum, and which, in so warm a climate, and with such ardent constitutions, appears to be a virtue of no easy attainment.

Our author says that he no where met with a nation so truly generous. Though he had nothing to give in exchange, yet during two days that he staid with them, he had bowls of milk brought to him as presents, night and morning, from every hut. The chief even obliged him to accept a lamb; and though our traveller's attendants were not destitute of provisions, he would give them also several sheep with which to regale themselves; a degree of generosity of which a proper estimate can be formed only by those who know something of savage manners and savage penury.

The practice of semi-castration prevails among the Gheyssequas, and among them only of all the Hottentot tribes; and it prevails in all their hordes without exception. Our author convinced himself of this fact by his own eyes; for the men were so complaisant, that, if he had chosen, he might have inspected the whole horde. Many travellers have written upon the subject of this whimsical operation; but they do not agree either as to its origin, the motives that lead to its invention, or the nations by whom it is practised. Kolben, who says that it commonly consists in the extraction of the left testicle, represents it as a religious ceremony, a general and sacred law, with all the Hottentots indiscriminately; but this is unquestionably false. (See HOTTENTOTS, *Encycl.*) Others attribute it to the desire of the Gheyssequas to render themselves more fleet in running, an effect which it surely is not calculated to produce; and some have said that its intention is to prevent the too abundant propagation of the species. Yet Kolben, though he seems inclined to this last opinion, affirms that twins are not the less common on account of the operation. According to those whom M. Vaillant questioned on the subject, it is merely a mark of distinction, which their ancestors, being at war with the neighbouring nations, invented for the purpose of knowing one another; but, as he himself admits, this is a very improbable account of the matter, as they would surely have adopted, like the Loangocs, Pombocs, and Cormantins, marks of distinction

Chirgong. tion more easily discerned. Be this as it may, the operation among the Gbeyssiquas is performed by the father, commonly at the birth of the child, though sometimes not till he has completed his third year.

*Pennant's
View of
Hindoostan.*

GHIRGONG, the capital of *Ajam* in Hindoostan, is, according to Mr Pennant, situated in latitude $26^{\circ} 30'$ north. He does not state its longitude. It has four gates, and the city is encompassed with a bound hedge of bamboos. The Rajah's palace is surrounded by a causeway, planted on each side with a close hedge of bamboos, which serves instead of a wall. On the outside there is a ditch, which is always full of water. The Rajah's seat is adorned with lattice work and carving. Within and without have been placed plates of brass, so well polished, that when the rays of the sun strike upon them they shine like mirrors. It is an ascertained fact, that 3000 carpenters and 12,000 labourers were constantly employed in this work during two years before it was finished.

The Asiatic Researches speak much of the wealth of *Ajam*, and of the plenty and excellency of its natural productions, and that it abounds in all metals but tin. Gold is found in every part of the country by washing the sand of the rivers, and is one of the sources of revenue; 12,000, some say 20,000 people, are employed in that work, each of whom has from the Rajah certain wages. Its gum lac is excellent, and it is very productive of silk.

Among the fruits which this country produces are mangoes, plantains, jacks, oranges, citrons, limes, pine apples, and puniala, a species of tamarind, which has such an excellent flavour, that every person who tastes it prefers it to the plum. There are also cocoa nut trees, pepper vines, and areca trees. The sugar cane excels in softness and sweetness, and is of three colours, red, black, and white. There is ginger free from fibres, and betel vines. The strength of vegetation and fertility of the soil are such, that whatever seed is sown or slips planted they always thrive. The environs of *Chirgong* furnish small apricots, yams, and pomegranates; but as these articles are wild, and not assisted by cultivation and engraftment, they are very indifferent. The principal crop in this country consists in rice and lentiles. Wheat and barley are never sown; lignum aloes is also a production of this country. The silks are excellent, and resemble those of China, but they manufacture very few more than are required for use. They are successful in embroidering with flowers and in weaving velvet.—One of their great forests is inhabited by abundance of elephants: 6 or 700 may be taken in a year, but they are neglected by the natives, who have neither horses, camels, nor asses, such as are brought from other countries.

According to our author, "the people of *Ajam* are a base unprincipled nation, and have no fixed religion. They follow no rule but that of their own inclination, and make their own vicious minds the test of the propriety of their actions. They do not adopt any mode of worship practised either by heathens or Mahomedans, nor do they concur with any of the known sects which prevail among mankind; unlike the pagans of Hindoostan, they do not reject victuals which have been dressed by Moslems, and they abstain from no flesh except human. They even eat animals that have died a natural death."

Gibbon. On this passage, one of the ablest of our literary journalists observes, that in justice to the people of *Ajam*, we must remark, that the above account, extracted from the memoirs of Mir Jumla's expedition into that country, was composed by a rigid Mahomedan, at the court of that fanatical tyrant Aurengzebe. The author and his master saw, in the *Afamese*, only idolaters; and, in idolaters, the meanest of mankind. Their diet, though less restricted than that of the Hindoos of Bengal, is by no means promiscuous; and their religion does not in any way differ from that of Hindoostan,—as might easily be proved by their coins, inscribed with the names of Hindoo deities.

GIBBON (Edward, Esq.), the celebrated historian of the Decline and Fall of the Roman Empire, was born at Putney in the county of Surrey on the 27th of April 1737. He was the first child of the marriage of Edward Gibbon, Esq; and Judith Porten, the youngest daughter of a merchant of London.

The family of Gibbon appears to be ancient and honourable; and our author delights to trace his pedigree from John Gibbon architect to King Edward III. who possessed lands in the hundred and parish of Rolvenden, in the district which is now called the *Weald* of Kent. In that district the elder branch of the family still adheres to its native soil, without much increase or diminution of property; but the fortunes of the younger branch, from which sprung the subject of this memoir, were fluctuating. It is not, however, with his family, but with himself, that we are concerned.

So feeble was his constitution, and so precarious his life during his childish years, that at the baptism of each of his brothers (and they were five in number) his father's prudence successively repeated the name of Edward, that, in case of the death of the eldest son, this patronymick appellation might still be perpetuated in the family. His brothers and a sister were all snatched away in their infancy; and, in terms of affectionate gratitude, he attributes his own preservation to the more than maternal care of a maiden aunt, his mother's eldest sister. "Many anxious and solitary days (says he) did that dear and excellent woman consume in the patient trial of every mode of relief and amusement. Many wakeful nights did she sit by my bed-side in trembling expectation that each hour would be my last. Suffice it to say, that while every practitioner from Sloane and Ward to the Chevalier Taylor was successively summoned to torture or relieve me, the care of my mind was too frequently neglected for that of my health. Compassion always suggested an excuse for the indulgence of the master, or the idleness of the pupil; and the chain of my education was broken as often as I was called from the school of learning to the bed of sickness."

His education seems indeed to have been far from systematical. At the age of seven he was delivered into the hands of Mr John Kirby, who exercised about eighteen months the office of his domestic tutor, and of whom he writes in terms of respect. This man had been an indigent curate in Cumberland, and when forced by distress to leave his native country, he was introduced by his learning and his virtue to the family of Mr Gibbon, from whom he might have found at least a temporary shelter, had not an act of indiscretion again driven him into the world. One day reading prayers in the parish church, he most unluckily forgot the name

Gibbon. of King George; and his patron, a loyal subject, dismissed him with some reluctance and a decent reward. As our author describes his ancestors as hereditary Tories, and some of them as Jacobites, we think it not improbable that Mr Kirby may have been accustomed to omit the name of the King when reading prayers in the family; for otherwise he would have pronounced it mechanically in the church.

Be this as it may, our author, upon the dismissal of his tutor, was sent to Kingston upon Thames, to a school of seventy boys kept by Dr Wooddeson and his assistants. He does not represent himself either as happy or as having made great progress at that school. The want of strength and activity disqualified him for the sports of the field; his companions reviled him for the sins of his Tory ancestors; and his studies were frequently interrupted by sickness. After a real or nominal residence of near two years at Kingston, he was finally recalled (Dec. 1747) by the death of his mother. By this time he was well acquainted with Pope's Homer, the Arabian Nights Entertainments, Dryden's Virgil, and a translation of Ovid's Metamorphoses; and the entertainment which he received from these books gave him a taste for desultory reading.

After living a year with his maternal aunt, during which period he read many books on religious subjects too deep for the comprehension of a boy, he was in January 1749 entered in Westminster school, of which Dr John Nicholl was at that time head master. "There (says he) in the space of two years, interrupted by danger and debility, I painfully climbed into the third form; and my riper age was left to acquire the beauties of the Latin and the rudiments of the Greek tongue. Instead of audaciously mingling in the sports, the quarrels, and the connections of our little world, I was still cherished at home under the maternal wing of my aunt, who now lived in College-street; and my removal from Westminster long preceded the approach of manhood."

He was first carried to Bath for the recovery of his health; then to Winchester, where he lived in the house of a physician; then to Bath again, where he read with a clergyman some odes of Horace and some episodes of Virgil; after which an unsuccessful trial was made to renew his attendance at Westminster school. "It might now be apprehended (says he) that I should continue for life an illiterate cripple; but as I approached my sixteenth year, Nature displayed in my favour her mysterious energies: my constitution was fortified and fixed; and my disorders instead of growing with my growth, and strengthening with my strength, most wonderfully vanished." In consequence of this he was carried to Oxford; and before he had accomplished his sixteenth year, was, on April 3. 1752, matriculated a gentleman commoner of Magdalen college.

For the honour of that celebrated university, we would fain hope that the account which Mr Gibbon gives of Magdalen college is greatly exaggerated. He represents his tutors as totally regardless of his morals or his studies. Speaking of the first and best of them, for he had two, he says, "No plan of study was recommended for my use; no exercises were prescribed for his inspection; and, at the most precious season of youth,

whole days and weeks were suffered to elapse without labour or amusement, without advice or account." We shall make no other remark on this passage, than that from gentlemen, who must have been contemporary with Mr Gibbon at Magdalen, we have received different accounts of the college; and it is surely a very singular circumstance, that at this period of idleness, our author should have become enamoured of Sir John Marsham's *Canon Chronicus*, and have conceived the idea of writing an *Essay on the age of Sesostris*. Such, however, was the case. Not only was the essay planned, but part of it was written; and though he never finished it, he declares, that his solution of some difficulties in chronology was not devoid of ingenuity; but he goes on to vilify Oxford. "It might at least be expected (says he), that an ecclesiastical school should inculcate the orthodox principles of religion. But our venerable mother had contrived to unite the opposite extremes of bigotry and indifference: an heretic, or unbeliever, was a monster in her eyes; but she was *always*, or *often*, or *sometimes* (A), remiss in the spiritual education of her own children. Without a single lecture, either public or private, either Christian or Protestant, without any academical subscription, without any Episcopal confirmation, I was led by the dim light of my catechism to grope my way to the chapel and communion table, where I was admitted without a question, how far, or by what means, I might be qualified to receive the sacrament. Such almost incredible neglect was productive of the worst mischiefs. From my childhood I had been fond of religious disputation; nor had the elastic spring been totally broken by the weight of the atmosphere of Oxford. The blind activity of idleness urged me to advance without armour into the dangerous mazes of controversy; and, at the age of sixteen, I bewildered myself in the errors of the church of Rome."

This anxious is our author to account for his reconciliation to the Romish church by the negligence of the tutors of his college. This event took place on the 8th of June 1753, when, at the feet of a priest in London, he solemnly, though privately, abjured the errors of heresy. An elaborate controversial epistle, approved by his director, and addressed to his father, announced and justified the step he had taken; and the old gentleman, in the first fall of passion, divulging the secret, the gates of Magdalen college were shut against the convert. It was necessary therefore to form a new plan of education; and our young Catholic, by the advice of Mr Eliot (afterwards Lord Eliot), was settled, on the 30th of June, under the roof and tuition of Mr Pavilliard, a Calvinist minister at Lausanne in Switzerland.

He represents his situation there as at first extremely uncomfortable. He could not avoid contrasting a small chamber, ill contrived and ill furnished, with his elegant apartment in Magdalen college; and M. Pavilliard being entrusted with the management of his expences, he felt himself degraded from the rank of gentleman commoner to that of a school-boy. He began, however, gradually to be reconciled to his fate; and his love of reading returned, which, he says, had been chilled by the air of Oxford. He rapidly acquired the French language; and of his tutor he says, "My obligations

to

(A) Surely *always* and *sometimes* are words of very different import: why are they used then, in this sentence, as synonymous?

Gibbon.

to the lessons of Mr Pavilliard gratitude will not suffer me to forget. He was endued with a clear head and a warm heart; his innate benevolence had assuaged the spirit of the church; he was rational, because he was moderate: in the course of his studies, he had acquired a just, though superficial knowledge of most branches of literature; by long practice he was skilled in the arts of teaching; and he laboured with assiduous patience to know the character, gain the affection, and open the mind of his English pupil."

Under the tuition of this amiable preceptor he describes his progress in the French and Latin classics, in history, geography, logic, and metaphysics, as uncommonly rapid; and he allows to the same man a handsome share of the honour of reclaiming him from the errors of popery. The various discriminating articles of the Romish creed disappeared like a dream; and, after a full conviction, on Christmas-day 1754, he received the sacrament in the church of Lausanne. Thus had our author communicated with three different societies of Christians before the completion of his eighteenth year; and as such changes from church to church are always dangerous, we need not wonder that, in a mind so ill-furnished as Mr Gibbon's then was for theological investigations, they paved the way for his last change to Deism. At present, however, he suspended his religious inquiries, acquiescing (as he says) with implicit belief in the tenets and mysteries which are adopted by the general consent of Catholics and Protestants.

He continued to prosecute his studies with ardour. Under Mr Pavilliard he learned the Greek alphabet, the grammar, and the pronunciation of the language according to the French accent, and soon made himself master of the works of Homer, Herodotus, and Xenophon. During two winters he attended the private lectures of M. de Traytorrens, who explained the elements of algebra and geometry as far as the conic sections of the Marquis de l'Hôpital; but in mathematics he was content (he says) to receive the passive impression of his professor's lectures, without any active exercise of his own powers. In the writings of Grotius and Puffendorf he studied the duties of a man, the rights of a citizen, the theory of justice, and the laws of peace and war, which have had some influence on the practice of modern Europe. "Locke's treatise on government (says he) instructed me in whig principles, which are founded rather in reason than experience; but my delight was in the frequent perusal of Montesquieu, whose energy of style and boldness of hypothesis were powerful to awaken and stimulate the genius of the age"

We have been thus minute in our account of Mr Gibbon's studies, because it furnishes perhaps the most useful lesson which can be drawn from the whole history of his life. His education had been rendered irregular, and had been often interrupted by ill-health and a feeble constitution; but as soon as he was able, and had an opportunity, he applied with ardour to the cultivation of letters, and his works bear witness that his labour was crowned with success. "This part of his story therefore (to use the words of Johnson) well deserves to be remembered. It may afford useful admonition and powerful encouragement to men whose abilities have been made, for a time, useless, and who, having lost one part of life in idleness, are tempted to throw away the remainder in despair."

Gibbon.

In the year 1757 Voltaire arrived at Lausanne, and our young student's desire to see the man who was at once a poet, an historian, and, as he deemed himself, the prince of philosophers, was ardent, and easily gratified. He was received by the vain and arrogant Frenchman with civility as an English youth, but could not boast of any peculiar notice or distinction. "The highest gratification (says he) which I received from Voltaire's residence at Lausanne, was the uncommon circumstance of hearing a great poet declaim his own productions on the stage. His declamation was fashioned to the pomp and cadence of the old stage; and he expressed the enthusiasm of poetry rather than the feelings of Nature."

About this time Mr Gibbon became enamoured of Mademoiselle Susan Curchod, the daughter of the minister of Crasse, in the mountains which separate the Pays de Vaud from the county of Burgundy. In terms of rapture he describes this lady as possessed of every accomplishment which could adorn her sex. She listened to the voice of truth and passion; her parents honourably encouraged the connection; and our author indulged in the dream of felicity: but on his return to England, he discovered that his father would not hear of this strange connection, and that without his consent he was destitute and helpless. "After a painful struggle (says he) I yielded to my fate. I sighed as a lover, I obeyed as a son, and my wound was insensibly healed by time, absence, and the habits of a new life." The lady consoled herself by giving her hand to M. Neckar, then a rich banker of Paris, afterwards the minister, and at last one of the destroyers of the French monarchy.

In the spring of the year 1758 our author was recalled to England. On his arrival in London he hastened to the house of his aunt, Mrs Porten, who had been the guardian of his tender years; for though his father was in town awaiting his arrival, he knew not how he should be received by a parent who had parted with him in anger, and given him a stepmother in his absence. His reception was more agreeable than he expected. His father received him as a man and a friend; and the manners of Mrs Gibbon were such, that, after some reserve on his side, she and he easily adopted the tender names and genuine characters of mother and son; and, by the indulgence of these parents, he was left at liberty to consult his own taste or reason in the choice of place, of company, and of amusements. In London he had few acquaintances, and hardly any friends; and being accustomed to a very small society at Lausanne, he preferred the retirement of the country to the bustle of that over-grown metropolis, where he found hardly any entertainment but in the theatres.

Before he left Lausanne he had begun a work on the study of ancient literature, which was suggested by the desire of justifying and praising the object of a favourite pursuit. "In France (says he), to which my ideas were confined, the learning and language of Greece and Rome were neglected by a philosophic age. The guardian of those studies, the Academy of Inscriptions, was degraded to the lowest rank among the three royal societies of Paris: The new appellation of *Erudits* was * See Le
contemptuously applied to the successors of Lipsius and
Cafaubon; and I was provoked to hear *, that the ex-
ercise of the memory, their sole merit, had been super-
ceded by the nobler faculties of the imagination and the
judgment die.
par D'A-
lembert à
l'Encyclopæ-

Gibbon. judgment. I was ambitious of proving by my own example, as well as by my precepts, that all the faculties of the mind may be exercised and displayed by the study of ancient literature." This laudable ambition continued; and in his father's house at Beriton in Hampshire he finished his *Essai sur l'Etude de la Littérature*; which, after being revised by Mallet the poet and Dr Maty of the British museum, was, in 1761, published in a small 12mo volume.

The subjects of taste, criticism, and philosophy, which in this work came under our young author's consideration, could hardly promise much novelty of remark. Some former observations, however, he appears to have placed in a new and pleasing point of view; advancing, moreover, some ingenious conjectures, and displaying no inconsiderable erudition. Yet, by his own account, he was at this time almost a stranger to the writers of Greece; and when he quotes them, it is probable that the quotations are given at second hand. To this essay was prefixed a dedication to his father in the English language, which exhibits the author himself in a very amiable light; but if his reputation had depended solely upon this youthful attempt, the name of Gibbon would have been lost in oblivion. Yet he seems, even in his riper years, to have been delighted with it himself, and to have considered its merits as equal to those of his later productions; but Milton, it is said, preferred the *Paradise Regained* to the *Paradise Lost*.

Before the publication of this essay, the author, at his own desire, had been appointed a captain in the South Hampshire militia, in which he served upwards of two years. At first, the company of rustic and illiterate officers, and the bustle of a military life, were extremely disagreeable to him, as they interrupted his studies; but he admits, that his military services, his bloodless and inglorious campaigns, as he calls them, were, on the whole, beneficial, as they brought him acquainted with English manners, English parties, and English principles, to which his foreign education and reserved temper had hitherto kept him an entire stranger. In the camp and in quarters he had even found leisure, after the first seven or eight months of his service, to read a great deal of Greek, and to plan different historical works, to the composition of which he seems to have thought that he was born with an innate propensity. He always talks of himself as a philosopher; but surely a more unphilosophical persuasion than this has seldom been admitted.

At the end of the war he went again abroad, and reached Paris on the 28th of January 1763, only 36 days after the disbanding of the militia in which he had borne the commission of a captain. In that metropolis he staid not long. He visited palaces, churches, gardens, and theatres, and was introduced to D'Alembert and Diderot, then considered as at the head of French science. From Paris he proceeded to Switzerland, and once more took up his residence at his favourite Lausanne. Voltaire's impieties had forced him from that town to his own castle at Ferney, where our author once visited him, without (he says) courting his more intimate acquaintance.

The society in which Mr Gibbon most delighted during his second residence at Lausanne was a very singular one. "It consisted of fifteen or twenty unmarried ladies of genteel families; the eldest perhaps about

twenty, all agreeable, several handsome, and two or three of exquisite beauty. At each other's houses they assembled almost every day, without the controul, or even the presence of a mother or an aunt; they were trusted to their own prudence, among a crowd of young men of every nation in Europe. They laughed, they sung, they danced, they played at cards, they acted comedies; but in the midst of this careless gaiety, they respected themselves, and were respected by the men; the invisible line between liberty and licentiousness was never transgressed by a gesture, a word, or a look, and their virgin chastity was never sullied by the breath of scandal or suspicion."

We readily agree with our author that this singular institution was expressive of the innocent simplicity of Swiss manners; and we only regret that he had not the same respect for the ladies of his own country as for those frolic females of Switzerland. He would not, in that case, have stained some of his most brilliant pages with obscene ribaldry.

We shall not follow him in his ramble through Italy, or repeat his remarks on the towns which he visited. It is sufficient, in such a sketch as this, to inform our readers, that it was at Rome on the 15th of October 1764, as he sat musing amidst the ruins of the Capitol, that the idea of his great work first started into his mind. But his original plan was circumscribed to the decay of the city rather than of the empire.

From carrying even this contracted plan into execution he was for some years diverted. On the 25th of June 1765 he arrived from Italy at his father's house in Hampshire, and found that he had filial duties to perform which interrupted his studies and disturbed his quiet. His father had involved himself in difficulties from which he could be extricated only by selling or mortgaging part of his estate; and to such sale or mortgage our author cheerfully consented. He regrets on this occasion that he had not "embraced the lucrative pursuits of the law or of trade, the chances of civil office or India adventure, or even the fat slumbers of the church;" and it is to be hoped that, when he thought even of *slumbering* in the church, he had still some faith in revealed religion. He wasted some time in planning a history of the revolutions of Switzerland, and even wrote part of it in the French language, which, by the advice of friends, he however suppressed. We next find him engaged with a friend in a Journal entitled *Memoires Littéraires de la Grande Bretagne*, of which two volumes for the years 1767 and 1768 were published, and a third almost completed, when his friend, a native of Switzerland, was engaged, through his interest, as travelling governor to Sir Richard Worsley, and the Journal was, of course, abandoned. He then entered the lists with Warburton; whose interpretation of the sixth book of the *Æneid* he attacked with great petulance and with much success. The bishop of Gloucester was by this time in a state of great mental decay, which was peculiarly unfortunate for our author; for had his Lordship enjoyed his pristine vigour, he would probably have given Mr Gibbon such a chastisement as might have made him more modest afterwards when writing the history of the Decline and Fall of the Roman Empire.

To that great work he now sat down seriously; and the history which he gives of his preparatory studies sufficiently

Gibbon. sufficiently accounts for the inaccuracy of his quotations. Through the darkness of the middle ages he explored his way in the annals and antiquities of Italy by the learned Muratori and other moderns; and seems to acknowledge that, from the beginning to the end of his work, he frequently contented himself with authorities furnished at second hand.

At last, in 1776, the first volume of his history was published by Cadell the bookseller and Strahan the printer; and the success of it far surpassed his expectation. The encomiums lavished on it by Dr Robertson and Mr Hume in letters to the author, and the fulsome compliments which those three eminent historians paid to each other, are melancholy specimens of lettered littleness and vanity. The second and third volumes appeared in 1781; the fourth, fifth, and sixth in 1787; and Mr Gibbon's fame was established as a historian. The work was admired both by natives and by foreigners, and translated into several of the languages of Europe. Dr Zimmerman represents the author as excelling perhaps Hume and Robertson, who were historians of the first rank. All the dignity (he adds), all the charms of historic style, are united in Gibbon: his periods are melody itself, and all his thoughts have nerve and vigour." This praise, however, must not be admitted without exception. Few writers, indeed, were possessed of such popular talents as our historian. The acuteness of his penetration, and the fertility of his genius, have been seldom equalled, and scarcely ever surpassed. He seizes, with singular felicity, on all the most interesting facts and situations; and these he embellishes with the utmost luxuriance of fancy and elegance of style. His periods are full and harmonious; his language is always well chosen, and is frequently distinguished by a new and peculiarly happy adaptation. His epithets, too, are in general beautiful and happy; but he is rather too fond of them. The uniform stateliness of his diction sometimes imparts to his narrative a degree of obscurity, unless he descends to the miserable expedient of a note, to explain the minuter circumstances. His style, on the whole, is much too artificial; and this gives a degree of monotony to his periods, which extends, we had almost said, to the turn of his thoughts.

A more serious objection is his attack upon Christianity; the loose and disrespectful manner in which he mentions many points of morality regarded as important on the principles of natural religion; and the indecent allusions and expressions which too often occur in the work.

An attack upon Christianity is not censurable merely as such; it may proceed from the purest and most virtuous motives: but, in that case, the attack will never be carried on in an insidious manner, and with improper weapons, and Christianity itself, so far from dreading, will invite every mode of fair and candid discussion. Our historian, it must be confessed, often makes, when

Gibbon. he cannot readily find, an opportunity to insult the Christian religion. Such, indeed, is his eagerness in the cause, that he stoops to the most despicable pun, or to the most awkward perversion of language, for the pleasure of turning the scripture into ribaldry, or calling Jesus an impostor.

Yet of the Christian religion has Mr Gibbon himself observed, that it "contains a pure, benevolent, and universal system of ethics, adapted to every duty and every condition of life." Such an acknowledgment, and from such a writer, too, ought to have due weight with a certain class of readers, and of authors likewise, and lead them seriously to consider, how far it is consistent with the character of good citizens, to endeavour, by sly insinuations, oblique hints, indecent sneer, and profane ridicule, to weaken the influence of so pure and benevolent a system as that of Christianity, acknowledged to be admirably calculated for promoting the happiness of individuals, and the welfare of society.

Mr Hayley, in his poetical Essay on History, after a splendid panegyric on the arduous labours of his friend, laments the irreligious spirit by which he was actuated.

Think not my verse means blindly to engage
In rash defence of thy profaner page!
Though keen her spirit, her attachment fond,
Base service cannot suit with Friendship's bond;
Too firm from Duty's sacred path to turn,
She breathes an honest sigh of deep concern,
And pities Genius, when his wild career
Gives Faith a wound, or Innocence a tear.
Humility herself divinely mild,
Sublime religion's meek and modest child,
Like the dumb son of Cræsus, in the strife,
Where force assail'd his father's sacred life,
Breaks silence, and with filial duty warm,
Bids thee revere her parent's hallowed form (B)!

The part of the history which gave such offence to his own friend, as well as to the friends of the Christian religion in general, was the account which our historian has given of the progress and establishment of Christianity in the two last chapters of his first volume; in which he endeavours to prove, that the wonderful triumph of that religion over all the established religions of the earth, was not owing to any miraculous attestations to its truth, but to five secondary causes which he enumerates; and that Christianity, of course, could not be of divine origin. Several answers appeared on this occasion, written, as we may naturally suppose, with different degrees of temper and ability (C).

One of them only, Mr Davis, who had undertaken to point out various instances of misrepresentation, inaccuracy, and even plagiarism in his account, did our historian condescend particularly to answer, and that in a tone of proud contempt and confident superiority. To this

(B) Herodotus relates, that a Persian soldier, at the storming of Sardis, was preparing to kill Cræsus, whose person he did not know, and who, giving up all as lost, neglected to defend his own life. A son of the unfortunate monarch, who had been dumb from his infancy, and who never spoke afterward, found utterance in that trying moment, and preserved his father by exclaiming, 'O kill not Cræsus!'

(C) Dr Chelsum, Dr Randolph, Dr Watson (bishop of Llandaff), Lord Hailes, Dr White, Mr Apthorpe, Mr Davis, and Mr Taylor, the author of 'The Letters of Ben Mordecai.'

Gibbon, this Mr Davis replied; and it is but justice to observe, that his reply bears evident marks of learning, judgment, and critical acumen, and that he has convicted our author of sometimes quoting inaccurately to serve a purpose. At his other answerers Mr Gibbon merely glanced, treating Dr Watson, however, with particular respect; but his posthumous memoirs shew how much he felt the attacks made on him by Lord Hailes, Dr White of Oxford, and Mr Taylor. To Dr Priestley, who, in his *History of the Corruptions of Christianity*, threw down his gauntlets at once to Bishop Hurd and the historian of the Roman empire, and who presented the latter with a copy of his book, declaring at the same time, that he sent it not as a gift but as a *challenge*; he wrote in such terms as produced a correspondence, which certainly added not to the honour of the dissenting divine.

At the beginning of the memorable contest between Great Britain and America, our author was returned, by the interest of Mr Eliot (now Lord Eliot), for the borough of Liskeard, and supported, with many a sincere and silent vote, the rights, though not, perhaps, the interest, of the mother country. "After a fleeting illusive hope, prudence condemned me (says he) to acquiesce in the humble station of a mute." I was not armed by Nature and education with the intrepid energy of mind and voice.

Vincentem strepitus, et natum rebus agendis.

Timidity was fortified by pride; and even the success of my pen discouraged the trial of my voice."

That pen, however, was useful to the ministry whom he could not support by his eloquence in the house. At the request of the Lord Chancellor and Viscount Weymouth, then secretary of state, he vindicated, in a very able manner, against the French manifesto, the justice of the British arms; and his *Memoire Justificatif* was delivered as a state paper to the courts of Europe. He was rewarded for this service with the place of one of the lords commissioners of trade and plantations; and kept it, till the board was abolished by Mr Burke's reform bill. For accepting this place he was severely, but most unjustly, blamed by some of the leaders of the opposition, as if he had deserted a party in which he had never enlisted, and to the principles of which he was rendered inimical both by family prepossession and by his own judgment.

On the downfall of Lord North's administration, Mr Gibbon was of course in the opposition deprived of an office, without the salary of which he could not conveniently support the expence of living in London. The coalition was indeed soon formed, and his friends were again in power; but having nothing to give him immediately, they could not detain him in parliament or even in England. He was tired of the bustle of the metropolis, and sighed once more for the retirement of Lausanne, at which he arrived before the overthrow of the coalition ministry, and where he lived happily till the last years of his life. It was in this retreat that he wrote the fourth, fifth, and sixth volumes of his history; and he left it only for a year to superintend the publication of these volumes in London. This great work being concluded, he returned to the banks of the Lemane lake, but found his enjoyments damped by the distress, and soon afterwards by the death, of his oldest and

dearest Swiss friend. Lausanne had now lost much of its attraction; the French revolution had crowded it with unfortunate emigrants, who could not be cheerful themselves or excite the cheerfulness of others; and the demons of democracy had begun to poison the minds of the sober citizens with principles which Mr Gibbon had always held in abhorrence. Speaking of these principles and their effects in Switzerland, he adds, "I beg leave to subscribe my assent to Mr Burke's creed on the revolution of France. I admire his eloquence, I approve his politics, I adore his chivalry, and I can almost excuse his reverence for church establishments. While the aristocracy of Berne protects the *happiness*, it is superfluous to inquire whether it be founded in the *rights* of men: the economy of the state is liberally supplied without the aid of taxes; and the magistrates *must* reign with prudence and equity, since they are unarmed in the midst of an armed nation."

It was against the beneficent and mild government of Berne that the emissaries of France contrived to excite the discontents of the people, by insinuating into their simple and untutored minds their own wild notions of liberty and equality. From the effects of this Gallic frenzy, which began to be very visible so early as the beginning of the year 1792, Mr Gibbon resolved to take shelter in England, and to abandon, for some time at least, what he called his paradise at Lausanne. Difficulties intervened, and forced him to postpone his journey from week to week, and from month to month; but on receiving the accounts of Lady Sheffield's death, he hastened to administer consolation to his friend, and arrived safe in London in the beginning of June 1793.

He continued in good health and spirits through the whole of the summer; but his constitution had suffered much from repeated attacks of the gout, and from an incipient dropsy in his ancles. The swelling of his ancles, however, subsided; but it was only in consequence of the water flowing to another place: and being repeatedly tapped for a *hydrocele*, he at last sunk under it, and died at his lodgings in St James's street, London, on the 16th of January 1794.

To draw a character at once general and just of this extraordinary man, would be difficult perhaps to one who had enjoyed the pleasure of his acquaintance, and must be impossible to those to whom his person was a stranger. Of the extent of his erudition there can be but one opinion; but various opinions may be held respecting the accuracy of his knowledge. Lord Sheffield, who knew him well, and loved him much assures us, that his conversation was still more captivating than his writings: but this could not result from the brilliancy of his wit; for of wit he declares himself that he had none. His memory was capacious and retentive, his penetration uncommon, and his colloquial eloquence ready and elegant; so that he could illustrate almost any topic of conversation from the copious stores of his own mind. From his private correspondence, and a journal not written for the public eye, he appears to have been a dutiful son, a loyal subject, and an affectionate and steady friend; but it is difficult to reconcile with so much moral and political worth his unfair and unmanly sneers at the religion of his country.

GIBRALTAR is a fortress of immense strength, of which a very full account has been given in the *Encyclopædia*.

Gibraltar. *cyclopædia*. Nothing, however, is in that article said of the natural history of the mountain on which the fortress is built, though, to men of science, that subject must be as interesting as a detail of sieges. This defect we are enabled to supply by means of Major Imrie's mineralogical description of Gibraltar, which is published in the fourth volume of the Transactions of the Royal Society of Edinburgh; and, we are persuaded, the following abstract of that elegant memoir will afford rational entertainment to many of our readers.

"The form of this mountain is oblong; its summit a sharp craggy ridge; its direction is nearly from north to south; and its greatest length, in that direction, falls very little short of three miles. Its breadth varies with the indentations of the shore, but it nowhere exceeds three quarters of a mile. The line of its ridge is undulated, and the two extremes are somewhat higher than its centre.

"The summit of the Sugar Loaf, which is the point of its greatest elevation towards the south, is 1439 feet; the Rock Moutar, which is the highest point to the north, is 1350; and the Signal House, which is nearly the central point between these two, is 1276 feet above the level of the sea. The western side of the mountain is a series of rugged slopes, interspersed with abrupt precipices. Its northern extremity is perfectly perpendicular, except towards the north-west, where what are called the Lines intervene, and a narrow passage of flat ground that leads to the isthmus, and is entirely covered with fortification. The eastern side of the mountain mostly consists of a range of precipices; but a bank of sand, rising from the Mediterranean in a rapid acclivity, covers a third of its perpendicular height. Its southern extremity falls, in a rapid slope from the summit of the Sugar Loaf, into a rocky flat of considerable extent, called Windmill Hill.

"The principal mass of the mountain rock consists of a grey, dense (what is generally called primary) marble; the different beds of which are to be examined in a space of 1350 feet of perpendicular height, which it presents to Spain in a conical form. These beds, or strata, are of various thickness, from 20 to upwards of 40 feet, dipping in a direction from east to west, nearly at an angle of 35 degrees. In some parts of the solid mass of this rock are found testaceous bodies entirely transmuted into the constituent matter of the rock, and their interior hollows filled up with calcareous spar; but these do not occur often in its composition, and its beds are not separated by any intermediate strata.

"The caves of Gibraltar are many, and some of them of great extent. That which most deserves attention and examination is called St Michael's Cave, which is situated upon the southern part of the mountain, almost equally distant from the Signal Tower and the Sugar Loaf. Its entrance is 1000 feet above the level of the sea: This entrance is formed by a rapid slope of earth, which has fallen into it at various periods, and which leads to a spacious hall, incrustated with spar, and apparently supported in the centre by a large massy stalactitical pillar. To this succeeds a long series of caves of difficult access. In these cavernous recesses, the formation and process of stalactites is to be traced, from the slimy quilt-like cone, suspended from the roof, to the robust trunk of a pillar, three feet in diameter, which

rises from the floor, and seems intended by Nature to support the roof from which it originated.

"The only inhabitants of these caves are bats, some of which are of a large size. The soil, in general, upon the mountain of Gibraltar is but thinly sown; and in many parts that thin covering has been washed off by the heavy autumnal rains, which have left the superficies of the rock, for a considerable extent, bare and open to inspection. In those situations, an observing eye may trace the effects of the slow, but constant, decomposition of the rock, caused by its exposure to the air, and the corrosion of sea-salts, which, in the heavy gales of easterly winds, are deposited with the spray on every part of the mountain. Those uncovered parts of the mountain rock also expose to the eye a phenomenon worthy of some attention, as it tends clearly to demonstrate, that, however high the surface of this rock may now be elevated above the level of the sea, it has once been the bed of agitated waters. This phenomenon is to be observed in many parts of the rock, and is constantly found in the beds of torrents. It consists of pot-like holes, of various sizes, hollowed out of the solid rock, and formed apparently by the attrition of gravel or pebbles, set in motion by the rapidity of rivers or currents in the sea.

"Upon the west side of the mountain, towards its base, some strata occur, which are heterogenous to the mountain rock: the first, or highest, forms the segment of a circle; its convex side is towards the mountain, and it slopes also in that direction. This stratum consists of a number of thin beds; the outward one, being the thinnest, is in a state of decomposition, and is mouldering down into a blackish brown or ferruginous coloured earth. The beds, inferior to this, progressively increase in breadth to 17 inches, where the stratification rests upon a rock of an argillaceous nature.

"This last bed, which is 17 inches thick, consists of quartz of a blackish blue colour, in the septa or cracks of which are found fine quartz crystals, colourless, and perfectly transparent. These crystals are composed of 18 planes, disposed in hexangular columns, terminated at both extremities by hexangular pyramids. The largest of those that Major Imrie saw did not exceed one-fourth of an inch in length: They, in general, adhere to the rock by the sides of the column, but are detached without difficulty. Their great degree of transparency has obtained them the name of *Gibraltar diamonds*."

Much has been said of the fossil bones found in the rock of Gibraltar; and the general idea which exists concerning them is, that they are found in a petrified state, and enclosed in the solid calcareous rock; but this, says Major Imrie, is a mistake, which could arise only from inaccurate observation and false description.

"In the perpendicular fissures of the rock, and in some of the caverns of the mountain (all of which afford evident proofs of their former communication with the surface), a calcareous concretion is found, of a reddish brown ferruginous colour, with an earthy fracture, and considerable induration, enclosing the bones of various animals, some of which have the appearance of being human. These bones are of various sizes, and lie in all directions, intermixed with shells of snails, fragments of the calcareous rock, and particles of spar; all of which materials are still to be seen in their natural uncombined

states,

Gibraltar. flates, partially scattered over the surface of the mountain. These having been swept, by heavy rains at different periods, from the surface into the situations above described, and having remained for a long series of years in those places of rest, exposed to the permeating action of water, have become enveloped in, and cemented by, the calcareous matter which it deposits.

“The bones, in this composition, have not the smallest appearance of being petrified; and if they have undergone any change, it is more like that of calcination than that of petrification, as the most solid parts of them generally admit of being cut and scraped down with the same ease as chalk,

“Bones combined in such concretions are not peculiar to Gibraltar: they are found in such large quantities in the country of Dalmatia, and upon its coasts in the islands of Cherso and Osero, that some naturalists have been induced to go so far as to assert, that there has been a regular stratum of such matter in that country, and that its present broken and interrupted appearance has been caused by earthquakes, or other convulsions, experienced in that part of the globe. But, of late years, a traveller (Abbé Alberto Fortis) has given a minute description of the concretion in which the bones are found in that country: And by his account it appears, that with regard to situation, composition, and colour, it is perfectly similar to that found at Gibraltar. By his description, it also appears that the two mountain rocks of Gibraltar and Dalmatia consist of the same species of calcareous stone; from which it is to be presumed, that the concretions in both have been formed in the same manner and about the same periods.

“Perhaps if the fissures and caves of the rock of Dalmatia were still more minutely examined, their former communications with the surface might yet be traced, as in those described above; and, in that case, there would be at least a strong probability, that the materials of the concretions of that country have been brought together by the same accidental cause which has probably collected those found in the caverns of Gibraltar. Major Imrie traced, in Gibraltar, this concretion, from the lowest part of a deep perpendicular fissure, up to the surface of the mountain. As it approached to the surface, the concretion became less firmly combined, and, when it had no covering of the calcareous rock, a small degree of adhesion only remained, which was evidently produced by the argillaceous earth, in its composition, having been moistened by rain and baked by the sun.

“The depth at which these materials had been penetrated by that proportion of stalaçtital matter, capable of giving to the concretion its greatest adhesion and solidity, he found to vary according to its situation, and to the quantity of matter to be combined. In fissures, narrow and contracted, he found the concretion possessing a great degree of hardness at six feet from the surface; but in other situations more extended: and where a larger quantity of the materials had been accumulated, he found it had not gained its greatest degree of adhesion at double that depth. In one of the caves, where the mass of concretion is of considerable size, he perceived it to be divided into different beds, each bed being covered with a crust of the stalaçtital spar, from one inch to an inch and a half in thickness; which seems to indicate, that the materials have been carried in at

various periods, and that those periods have been very remote from each other. Gibraltar.

“At Rosia Bay, upon the west side of Gibraltar, this concretion is found in what has evidently been a cavern, originally formed by huge unshapely masses of the rock which have tumbled in together. The fissure, or cavern formed by the disruption and subsidence of those masses, has been entirely filled up with the concretion, and is now exposed to full view by the outward mass having dropped down in consequence of the encroachments of the sea. It is to this spot that strangers are generally led to examine the phenomenon; and the composition, having here attained to its greatest degree of hardness and solidity, the hasty observer, seeing the bones inclosed in what has so little the appearance of having been a vacuity, examines no further, but immediately adopts the idea of their being incased in the solid rock. The communication from this former chasm to the surface from which it has received the materials of the concretion, is still to be traced in the face of the rock, but its opening is at present covered by the base of the line wall of the garrison. Here bones are found that are apparently human; and those of them that appear to be of the legs, arms, and vertebræ of the back, are scattered among others of various kinds and sizes, even down to the smallest bones of small birds. Major Imrie found here the complete jaw-bone of a sheep; it contained its full complement of teeth, the enamel of which was perfect, and its whiteness and lustre in no degree impaired. In the hollow parts of some of the large bones was contained a minute crystallization of pure and colourless calcareous spar; but, in most, the interior part consisted of a sparry crust of a reddish colour, scarcely in any degree transparent.

“At the northern extremity of the mountain, the concretion is generally found in perpendicular fissures. The miners there, employed upon the fortifications in excavating one of those fissures, found, at a great depth from the surface, two skulls, which were supposed to be human; but, to the Major, one of them, if not both, appeared to be too small for the human species. The bone of each was perfectly firm and solid; from which it is to be presumed, that they were in a state of maturity before they were inclosed in the concretion. Had they appertained to very young children, perhaps the bone would have been more porous, and of a less firm texture. The probability is, that they belonged to a species of monkey, which still continues to inhabit, in considerable numbers, those parts of the rock which are to us inaccessible.

“This concretion varies, in its composition, according to the situation in which it is found. At the extremity of Princes Lines, high in the rock which looks towards Spain, it is found to consist only of a reddish calcareous earth, and the bones of small birds cemented thereby. The rock around this spot is inhabited by a number of hawks, that, in the breeding season, nestle here and rear their young; the bones in this concretion are probably the remains of the food of those birds. At the base of the rock, below King's Lines, the concretion consists of pebbles of the prevailing calcareous rock. In this concretion, at a very considerable depth under the surface, was found the under parts of a glass bottle, uncommonly shaped, and of great thickness; the colour of the glass was of a dark green.”

Gibraltar.

Major Imrie makes an apology for giving so minute a description of these fossil bones; but, in our opinion, the public is indebted to him for bestowing so much attention on a subject which all must admit to be curious, and which, from the strange inferences drawn from similar phenomena by modern philosophers, has become important as well as curious.

We cannot dismiss this article without noticing the subterraneous galleries constructed in the rock not only for the protection of the men during a siege, but also for placing cannon, to annoy the enemy, in situations inaccessible but by such means. The idea of forming these galleries was conceived by the late Lord Heathfield when governor, and by him, in some measure, carried into execution; though the plan was not completed till lately by General O'Hara. Of these galleries we have in the *Monthly Magazine* for April 1798 an animated account, which we shall insert in the writer's own words.

"The subterraneous galleries are very extensive, pierce the rock in several places and in various directions, and at various degrees of elevation; all of them have a communication with each other, either by flights of steps cut in the rock, or by wooden stairs where the passages are required to be very perpendicular.

"The centinels may now be relieved during a siege from one post to another in perfect safety; whereas, previously to the constructing of these galleries, a vast number of men were killed by the Spaniards while marching to their several stations. The width of these galleries is about twelve feet, their height about fourteen. The rock is broken through in various places, both for the purpose of giving light and for placing the guns to bear on the enemy. In different parts there are spacious recesses, capable of accommodating a considerable number of men. To these recesses they give names, such as St Patrick's Chamber, St George's Hall, &c. The whole of these singular structures have been formed out of the solid rock by blasting with gunpowder. Through the politeness of an officer on duty, a place called Smart's Reservoir was opened for our inspection, which is a great curiosity, and not generally permitted to be shewn. It is a spring at a considerable depth in the body of the rock, and is above 700 feet above the level of the sea; we descended into the cavern that contains it by a rope ladder, and with the aid of lighted candles proceeded through a narrow passage over crystallized protuberances of the rock till we came to a hollow, which appears to have been opened by some convulsion of Nature. Here, from a bed of gems, arises the salutary fount, clear as the brilliant of the east, and cold as the icicle. We hailed the nymph of the grot, and, prostrating ourselves, quaffed hygean nectar from her sparry urn. When restored to the light of day, we obtained, through the medium of the same gentleman, the key of St George's Hall, at which we arrived by a very intricate and gloomy path to the spacious excavation, which is upwards of an hundred feet in length, its height nearly the same. It is formed in a semicircular part of the rock; spacious apertures are broken through, where cannons of a very large calibre command the isthmus, the Spanish lines, and a great part of the bay. The top of the rock is pierced through, so as to introduce sufficient light to enable you to view every part of it. It appears almost incredible that so large an excavation could be formed by gunpowder, without blowing up

the whole of that part of the rock, and still more so, that they should be able to direct the operations of such an instrument, so as to render it subservient to the purpose of elegance. We found in the hall a table, placed, I suppose, for the conveniency of those who are traversing the rock. The cloth was spread, the wine went round, and we made the vaulted roof resound with the accents of mirth and the songs of conviviality."

These excavations are indeed very extraordinary works; but as the whole rock abounds with caverns, we wish that our author had inquired more particularly than he seems to have done, whether St George's Hall be wholly the work of art. From one of the passages which we have extracted from Major Imrie's memoir, we are led to think that it is not, or at least, that the concretion removed had not acquired the consistence of the more solid parts of the rock. If this was the case, much of the wonder will vanish, since the pick-axe and chisel were probably employed to give elegance to the vault, and even, in some degree, to direct the operation of the gunpowder.

GIMBOLS, are the brass rings by which a sea-compass is suspended in its box that usually stands in the binacle.

GIRT, in timber-measuring, is the circumference of a tree, though some use this word for the quarter or 4th part of the circumference only, on account of the great use that is made of it; for the square of this 4th part is esteemed and used as equal to the area of the section of the tree; which square therefore multiplied by the length of the tree, is accounted the solid content. This content, however, is always about one-fourth part less than the true quantity; being nearly equal to what this will be after the tree is hewed square in the usual way: so that it seems intended to make an allowance for the squaring of the tree.

GIRT Line, is a line on the common or carpenter's sliding rule, employed in casting up the contents of trees by means of their girt.

GLASS ETCHING, or *Engraving upon*, is in the article CHEMISTRY (*Encycl.*) said to be a new art; and as that acid which dissolves siliceous earth, and also glass, was first discovered in the year 1771 by Scheele, one might naturally imagine that the art of etching with it upon glass could not be older. By many others, as well as by us, it has indeed been noticed as a new invention; yet Professor Beckmann, whose laborious researches have brought many things to light, has proved, that so early as the year 1670 the art of etching upon glass was discovered by Henry Schwanhard, son of George Schwanhard, who was a celebrated glass-cutter, patronized by the Emperor Ferdinand III. about the middle of the last century. At the time of his death, 1667, the father practised his art at Prague and Ratibon. Whether the son followed the same business at the same towns, or removed to Nuremberg, is not very evident from the professor's history; but in the year above-mentioned, some *aqua regia* (*nitro muriatic acid*) having accidentally fallen on his spectacles, he was surprised to find the glass corroded by it, and become quite soft. He thus found himself in possession of a liquid by which he could etch writing and figures upon plates of glass.

Such is our information; but if it be admitted (and it would display unreasonable scepticism to question it), Schwanhard must either have improved the nitro-muriatic acid

Gimbols
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acid by some means or other unknown to us, or have confined his etchings to some particular kinds of glass; for the *fluoric* is the only acid, with which we are acquainted, that corrodes all glass. (See *CHEMISTRY-Index* in this *Supplement*). M. Beckmann indeed seems to think that he had discovered the *fluoric* acid itself; for in the year 1725 there appeared in a periodical work the following receipt for making a powerful acid, by which figures of every kind can be etched upon glass.

“When the *spiritus nitri per distillationem* has passed into the recipient, ply it with a strong fire, and when well dephlegmated, pour it, as it corrodes ordinary glass, into a Weldenburg flask. Then throw into it a pulverised green Bohemian emerald, otherwise called *hesphorus* (which, when reduced to powder, and heated, emits in the dark a green light), and place it in warm sand for 24 hours. Take a piece of glass well cleaned, and freed from all grease by means of a ley; put a border of wax round it, about an inch in height, and cover it all over with the above acid. The longer you let it stand so much the better; and at the end of some time the glass will be corroded, and the figures which have been traced out with sulphur and varnish will appear as if raised above the pane of glass.”

That the Bohemian emerald or *hesphorus* mentioned in this receipt is green sparry fluor, cannot, says the professor, be doubted; and he seems to have as little doubt of the receipt itself having passed from Schwanhard and his scholars to the periodical work of 1725, from which it has been lately inserted in the *Œconomische Encyclopedie* of Krunitz. This supposition certainly acquires a considerable degree of probability from the similarity of Schwanhard's method of etching to that which is here recommended, and which is to different from what is now followed. At present, the glass is covered with a varnish either of isinglass dissolved in water, or of turpentine oil mixed with a little white lead, through which the figures to be etched are traced as on copper; but Schwanhard, when he had drawn his figures, covered them with varnish, and then by his liquid corroded the glass around them. His figures, therefore, when the varnish was removed, remained smooth and clear, appearing raised from a dim or dark ground; and M. Beckmann, who persuaded some ingenious artists to make trial of this antient method of etching, declares, that such figures have a much better effect than those which are cut into the glass.

Before concluding this article, it may be worth while just to mention a proposal which has been lately made to employ glass instead of copper for throwing off prints in the rolling press. That it is possible to use glass plates of great thickness for this purpose, it would be rash to deny; but the superiority of such plates to those of copper we cannot conceive. If not broken in pieces in the rolling press, they would doubtless last longer; but the expence of them at first would probably be greater, and the engraving on them could not be so fine.

GLOSSOCOMMON, in mechanics, is a name given by Heron to a machine composed of divers dented wheels with pinions, serving to raise huge weights.

Glucina,
Gold.

GLUCINA (A), a peculiar earth discovered by Vauquelin in the beryl and the emerald. Its general properties are as follows: 1. It is white; 2. Inspid; 3. Insoluble in water; 4. Adhesive to the tongue; 5. Infusible; 6. Soluble in the fixed alkalis; 7. Insoluble in ammoniac; 8. Soluble in the carbonat of ammoniac; 9. Soluble in almost every one of the acids (except the carbonic and phosphoric acids), and forming salts of a saccharine taste; 10. Fusible with borax into a transparent glass; 11. Absorbs one fourth of its weight of carbonic acid; 12. Decomposes the aluminous salts; 13. Is not precipitable by well saturated hydro-sulphurets.

The specific characters of glucina, which are united in none of the other known earths, are: 1. Its salts are saccharine, and slightly astringent; 2. It is very soluble in the sulphuric acid by excess; 3. It decomposes the aluminous salts; 4. It is soluble in the carbonat of ammoniac; 5. Is completely precipitated from its solutions by ammoniac; 6. Its affinity for the acids is intermediate between magnesia and alumine.

One hundred parts of beryl contain 16 of glucina; but for the best method of analyzing the beryl, and of course obtaining the earth, we must refer our readers to the article *MINERALOGY* in this *Supplement*; and shall conclude this short article with a valuable and judicious remark of Vauquelin's.

“It almost always happens (says this able chemist), in the sciences of observation, and even in the speculative sciences, that a body, a principle, or a property, formerly unknown, though it may often have been used, or even held in the hands, and referred to other simple species, may, when once discovered, be afterwards found in a great variety of situations, and be applied to many useful purposes. Chemistry affords many recent examples of this truth. Klaproth had no sooner discovered the different substances with which he has enriched the science, but they were found in various other bodies; and if I may refer to my own processes, it will be seen, that after I had determined the characters of chrome, first found in the native red lead, I easily recognized it in the emerald and the ruby. The same has happened with regard to the earth of the beryl. I have likewise detected it in the emerald; in which, nevertheless, it was overlooked both by Klaproth and myself in our first analysis: so difficult it is to be aware of the presence of a new substance, particularly when it possesses some properties resembling those already known!”

GOLD, the most perfect of all the metals. See *CHEMISTRY-Index* in this *Supplement*.

It has been a very common opinion among metallurgists, that tin has the property of destroying the ductility of gold, on being melted with it even in very small quantities; and Dr Lewis adds, that even the vapours which arise from tin in the fire, make gold so brittle, that it flies in pieces under the hammer. This opinion was controverted by Stanesby Alchorne, Esq; of his Majesty's mint, who made a set of experiments, which, in his opinion, authorize a very different conclusion, viz. that though tin, like other inferior metals, will

(A) This name was given to the earth of beryl by the editors of the *Annales de Chimie*. Its most characteristic property being that it forms salts of a saccharine taste, they gave it a name derived from *γλυκαινα*, to render sweet. According to this etymology, should not the name be *Glycina*?

Gold.

will contaminate gold in proportion to the quantity mixed with it, yet there does not appear in tin any thing specifically inimical to that precious metal.

As we have elsewhere (see CHEMISTRY, n^o 1091, &c. *Encycl.*) enumerated these experiments, and admitted the conclusion drawn from them, it becomes our duty, in this place, to state what has been urged against that conclusion.

M. Tillet, being in his own mind persuaded that tin renders gold so brittle that it cannot be reduced to thin leaves, and far less be made to pass through the wire-plate but by virtue of repeated annealing, and peculiar treatment, which gold of the usual ductility does not require, determined, from respect to M. Alchorne, to repeat his experiments.

* *Memoirs of the Academy of Sciences at Paris for the year 1790.*

His first experiment* consisted in mixing 24 grains of fine gold with one of tin which contained no arsenic. He wrapped the grain of tin in the 24 grains of gold reduced to a very thin leaf, and placed the whole upon a piece of charcoal, so hollowed out as to support the mixed metal during fusion. He even sprinkled a small quantity of calcined borax upon the metal, in order that the fusion might be more sudden, that the metal might flow together, and the tin unite with the gold, without allowing time for it to become calcined. This alloy was speedily fused by the enameller's lamp, and reduced into a small button without any loss of weight. It was then flattened carefully beneath the hammer; but, notwithstanding his utmost precaution in this respect, it cracked, and at last broke into three pieces, its thickness then being a quarter of a line or thereabouts. He repeated this experiment with a double quantity as well of pure gold as of tin, and the result was the same.

He next alloyed 4 ounces of gold, of the fineness of 22 carats, with 1 gros 24 grains of tin deprived of arsenic, or, in other words, with 4 pennyweights of tin; and these two metals being reduced into small pieces, were mixed together, put into a crucible, and urged by the strong heat of a forge with two pair of bellows. When their fusion appeared to be complete, he poured the metal into a small ingot mould proportioned to the quantity.

The ingot thus obtained had lost scarcely any thing of the weight of the two metals that composed it; which was a proof that the tin had united and incorporated with the four ounces of gold. But on attempting to bend the ingot, which was about six inches long, and not more than two or three lines thick, he remarked, contrary to the nature of gold of 22 carats, that it was rigid, and would have required a considerable effort to give it any degree of curvature, or bring it to the flexibility it would have possessed if no tin had entered into its composition. Not satisfied, however, with the inference naturally flowing from this circumstance, he proceeded to the proper test by hammering, particularly with the edge of the hammer, in order that the bar might be lengthened, and by that means submitted to the most decisive proof. He did not observe, during the continuation of this process, till the bar was reduced to about two-thirds of its first thickness, that its edges were cracked, or exhibited much of the appearance of brittleness; but as he was apprehensive that this accident might happen by too long hammering, he divided the bar by cutting off the part

Gold.

which had been hammered out. This part was placed in the midst of lighted charcoal, in order that, by a moderate annealing, it might recover the state of malleability it possessed before it was hammered. But when he went to take it out of the fire, where it had undergone no greater heat than a cherry-red, he found it divided into two parts. After having suffered these to cool, he forged them again. They were extended with considerable ease, though with some cracks at the edges; but they did not yet satisfy the whole of his enquiries. He therefore annealed one of the two last mentioned pieces a second time, and reserved the other in its hard-hammered state to be passed between the laminating rollers. The annealed part, which might have the thickness of about a shilling, broke in the fire, though the heat was very gentle, into four or five portions. The longest of these portions, which best resisted the action of the fire, bent and twisted itself, and shewed, by this state of strong contraction in different directions, that it had tended to break and become divided into small portions, similar to those which had already separated from it.

Satisfied by this experiment that the piece of the mixed ingot which he had kept in its hammer-hardened state would not bear annealing, he determined to extend it still more between the rollers, setting them up very gradually, in order that the fracture, if it should take place, might be principally owing to the brittleness of the material, and not to the force of compression to which it was subjected. By this management he succeeded in extending the metal to double its length notwithstanding its hardness, and rendering it as thin as strong paper; though the edges were cracked through their whole length like the teeth of a saw. But this accident is not at all surprising, when it is considered that gold, though alloyed simply with copper, whatever may be the cause, does not possess its usual ductility, particularly when it is laminated very thin, without repeated annealing as the metal becomes hard.

Aware that the fracture of the pieces of gold might be attributed to an incomplete fusion, or unequal mixture of the two metals, he melted the whole ingot over again with the utmost precaution; but in vain. The metal was as brittle as formerly, and would not bear annealing.

He next fused six ounces of pure gold of 24 carats with 2 gros, or 6 penny-weights of tin, taking every possible precaution to have the metals completely mixed. When the whole was in perfect fusion, he poured the mixture into an ingot mould, and obtained an ingot rather longer and cleaner than the two former. As soon as it was cold he forged one of its extremities with the edge of the hammer. It was lengthened without any perceptible crack; and when it was reduced to the thickness of one line, or thereabouts, he cut it off for separate treatment. By moderate annealing it maintained its integrity; and, with the exception of a few cracks, it passed the laminating rollers without breaking. As he was fearful, nevertheless, that it might break in some part if he continued to laminate it, he gave it a slight annealing. It had scarcely acquired a cherry-redness between the charcoal, before it broke into five or six parts, some of which were simply bended or twisted, and others flat as they quit- ted the rollers. Among the annealed pieces of this extremity

Gold. extremity of the ingot, there was one sufficiently long, though a little curled, which he laminated a second time, with the determination of rendering it very thin without the least annealing. It acquired at least double the length it had at first without breaking; and, if we except the two sides of this plate which were cracked, the body, or main piece, was entire. It was spongy, and might be considered as if formed out of an ingot of common gold containing no tin, but not possessing the whole of its natural ductility.

"It follows, says M. Tillet, from these experiments, that gold, whether fine or alloyed, when perfectly fused with a small portion of the finest tin, acquires rigidity and hardness by the mixture; that it loses somewhat of its distinguishing colour; and that it may, indeed, by careful management, be extended to a certain degree by the hammer, or still better by the rollers; but that, as it cannot be annealed without danger of breaking, it is by this defect deprived of the essential advantage of recovering its original softness after it has been strongly hammer-hardened. It is not but by careful management in the use of the hammer, and by frequent annealing, that artists employed on works of gold and silver succeed in obtaining them without cracks, and bringing them to a state of perfection, without being obliged to have recourse to solder to repair the defects which excessive hardness under the hammer would occasion. How much, therefore, ought gold-workers, who continually have this metal in their hands, to be attentive to prevent the introduction of tin in their workshops, and never to employ such compounds of gold as are subject to break, or even to warp, while annealing? The expence of refining, which they would pay for depurating such compounds, would be of less consequence to them than the loss of time required for the careful management of such gold contaminated by tin, even if they did succeed in using it, and were not often forced to abandon, after much labour, a work nearly finished.

"If it be allowable (continues our author) to form conjectures on the cause of the fracture of plates of gold containing tin, when subjected to the annealing heat, it may be presumed, since tin very speedily melts, while gold requires a strong heat for its fusion, that the parts of the tin intermixed in a sort of proportional equality with those of the gold, tend to separate by a speedy fusion and at a very gentle degree of heat; that they remain without confidence between the parts of the gold, while the latter preserve the whole of their solidity, and do not lose it even by the annealing heat: whence it seems, that the parts of the precious metal, when ignited among the coals, having no longer the solid connection formed by the tin, but, on the contrary, having an infinite number of small cavities occupied by particles of that metal in fusion, must tend to disunion; whereas the same accident does not take place in the pieces which have resisted the annealing, and have been laminated after cooling, because the particles of tin have become solid by cooling, and have recovered their original state of union with the gold.

"This fracture of the compound does not take place with an alloy of gold and copper, for an opposite reason to that which has here been explained; namely, because these two metals require nearly the same heat for their fusion. The effect of annealing being there-

fore equal upon both, the metals, notwithstanding this treatment, preserve their natural confidence, even tho' the heat be carried near the point of fusion."

GOLD-Leaf. See *GOLD-LEAF* (*En cycl.*), where a full account is given from Dr Lewis of the process of gold-beating. In that article we have said that gold-leaf ought to be prepared from the finest gold; but Mr Nicholson, who in all probability knows much more of the matter than the author from whom our account was copied, assures us that this is a mistake, and that pure gold is too ductile to be worked between the gold-beater's skin. The newest skins will work the finest gold, and make the thinnest leaf, because they are the smoothest. Old skins, being rough or foul, require coarser gold. The finer the gold, the more ductile; inasmuch that pure gold, when driven out by the hammer, is too soft to force itself over the irregularities, but would pass round them, and by that means become divided into narrow slips. The finest gold for this purpose has three grains of alloy in the ounce, and the coarsest twelve grains. In general, the alloy is six grains, or one-eighth part. That which is called pale-gold contains three pennyweights of silver in the ounce. The alloy of leaf-gold is silver, or copper, or both, and the colour is produced of various tints accordingly. Two ounces and two pennyweights of gold is delivered by the master to the workman, who, if extraordinary skillful, returns two thousand leaves, or eighty books of gold, together with one ounce and six pennyweights of waste cuttings. Hence one book weighs 4.8 grains; and as the leaves measure 3.3 inches in the side, the thickness of the leaf is one two hundred and eighty-two thousandth part of an inch.

The yellow metal called Dutch gold is fine brass. It is said to be made from copperplates, by cementation with calamine, without subsequent fusion. Its thickness, compared with that of leaf gold, proved as 19 to 4, and under equal surfaces it is considerably more than twice as heavy as the gold. *Nicholson's Journal*, vol. 1st.

GOLDONI (Charles), was born at Venice in the year 1707. He gave early indications of his humorous character, as well as his invincible propensity to those studies which have rendered his name immortal. His father, perceiving that the darling amusement of his son was dramatic performances, had a small theatre erected in his own house, in which Goldoni, while yet an infant, amused himself with three or four of his companions, by acting comedies. Before he was sent to school, his genius prompted him to become an author. In the seventh and eighth years of his age, ere he had scarcely learned to read correctly, all his time was devoted to the perusing comic writers, among whom was *Ciognini*, a Florentine, little known in the dramatic commonwealth. After having well studied these, he ventured to sketch out the plan of a comedy, which needed more than one eye-witness of the greatest probability to verify its being the production of a child.

After having finished his grammatical studies at Venice, and his rhetorical studies at the Jesuit's college in Perugia, he was sent to a boarding-school at Rimini to study philosophy. The impulse of nature, however, superseded with him the study of Aristotle's works, so much in vogue in those times. He frequented the theatres with uncommon curiosity; and passing gradually

Gold,
Goldoni

Goldoni.

gradually from the pit to the stage, entered into a familiar acquaintance with the actors. When the season of comic performances was over, and the actors were to remove to Chiozza, young Goldoni made his escape in their company. This was the first fault he committed, which, according to his own confession, drew a great many others after it. His father had intended him to be a physician, like himself: the young man, however, was wholly averse to the study. He proposed afterwards to make him an advocate, and sent him to be a practitioner in Modena. An horrid ceremony of ecclesiastical jurisdiction, at which he was present, inspired him with a melancholy turn, and he determined to become a capuchin.

His father, perceiving the whimsical, inconstant humour of his son, feigned to second this proposal, and promised to go and present him to the guardian of the capuchins in Venice, in the hope that, after some stay in that extensive and merry city, his melancholy fit would cease. The scheme succeeded; for the young man, indulging in all the fashionable dissipation of the place, was cured of his foolish resolution. It was however necessary for him to be settled in some employment; and he was prevailed upon by his mother, after the death of his father, to exercise the profession of a lawyer in Venice. By a sudden reverse of fortune he was compelled to quit at once both the bar and Venice. He then went to Milan, where he was employed by the resident of Venice in the capacity of secretary; where becoming acquainted with the manager of the theatre, he wrote a farce, entitled *Il Gondoliere Veneziano*, the Venetian Gondolier; which was the first comic production of his that was performed and printed. Some time after, Goldoni broke with the Venetian resident, and removed to Verona.

There was in this place, at that time, the company of comedians of the theatre of St Samuel of Venice, and among them the famous actor *Cofali*, an old acquaintance of Goldoni, who introduced him to the manager. He began therefore to work for the theatre, and became insensibly united to the company, for which he composed several pieces. Having removed along with them to Genoa, he was for the first time seized with an ardent passion for a lady, who soon afterwards became his wife. He returned with the company to Venice, where he displayed, for the first time, the powers of his genius, and executed his plan of reforming the Italian stage. He wrote the *Momolo*, *Courtisan*, the *Squanderer*, and other pieces, which obtained universal admiration.

Feeling a strong inclination to reside some time in Tuscany, he repaired to Florence and Pisa, where he wrote *The Footman of Two Masters*, and *The Son of Harlequin lost and found again*. He returned to Venice, and set about executing more and more his favourite scheme of reform. He was now attached to the theatre of St Angelo, and employed himself in writing both for the company and for his own purposes. The constant toils he underwent in these engagements impaired his health. He wrote, in the course of twelve months, sixteen new comedies, besides forty-two pieces for the theatre; among these many are considered as the best of his productions. The first edition of his works was published in 1753, in 10 vols. 8vo. As he wrote afterwards a great num-

Goldoni.

ber of new pieces for the theatre of St Luca, a separate edition of these was published, under the title of *The New Comic Theatre*: among these was the *Terence*, called by the author his *favourite*, and judged to be the master-piece of his works. He made another journey to Parma, on the invitation of Duke Philip, and from thence he passed to Rome. He had composed 59 other pieces so late as the year 1761, five of which were designed for the particular use of Marquis Albergati Capacelli, and consequently adapted to the theatre of a private company. Here ends the literary life of Goldoni in Italy.

Through the channel of the French Ambassador in Venice, he had received a letter from Mr Zeuuzzi, the first actor in the Italian theatre at Paris, containing a proposal for an engagement of two years in that city. He accordingly repaired to Paris, where he found a select and numerous company of excellent performers in the Italian theatre. They were, however, chargeable with the same faults which he had corrected in Italy; and the French supported, and even applauded in the Italians, what they would have reprobated on their own stage. Goldoni wished to extend even to that country his plan of reformation, without considering the extreme difficulty of the undertaking. Scurrilities and jests, which are ever accompanied by actions, gestures, and motions, are the same in all countries, and almost perfectly understood even in a foreign tongue: while the beauties of sentiment and dialogue, and other things which lead to the understanding of characters and intrigues, require a familiar acquaintance with the tongue of the writer.

The first attempt of Goldoni towards his wished-for reform, was the piece called *The Father for Love*; and its bad success was a sufficient warning to him to desist from his undertaking. He continued, during the remainder of his engagement, to produce pieces agreeable to the general taste, and published twenty-four comedies; among which *The Love of Zelinda* and *Lindor* is reputed the best.

The term of two years being expired, Goldoni was preparing to return to Italy, when a lady, reader to the dauphiness, mother to the late king, introduced him at court, in the capacity of Italian master to the princesses, aunts to the king. He did not live in the court, but resorted there at each summons, in a post-chaise sent to him for the purpose. These journeys were the cause of a disorder in the eyes, which afflicted him the rest of his life; for being accustomed to read while in the chaise, he lost his sight on a sudden, and in spite of the most potent remedies, he could never afterwards recover it entirely. For about six months lodgings were provided him in the chateau of Versailles. The death, however, of the dauphin, changed the face of affairs. Goldoni lost his lodgings, and only, at the end of three years, received a bounty of 100 louis in a gold box, and the grant of a pension of four thousand livres a-year. This settlement would not have been sufficient for him, if he had not gained, by other means, farther sums. He wrote now and then comedies for the theatres of Italy and Portugal; and, during these occupations, was desirous to shew to the French that he merited a high rank among their dramatic writers. For this purpose, he neglected nothing which could be of use to render himself master of the French language.

He

Goldoni, He heard, spoke, and conversed so much in it, that, in his 62d year, he ventured to write a comedy in French, and to have it represented in the court theatre, on the occasion of the marriage of the king.

This piece was the *Bourru Bienfaisant*; and it met with so great success, that the author received a bounty of 150 louis from the king, another gratification from the performers, and considerable sums from the booksellers who published it. He published, soon after, another comedy in French, called *L'Avare Fastueux*. After the death of Louis XV. Goldoni was appointed Italian teacher to the Princess Clotilde, the present princess of Piedmont; and after her marriage he attended the late unfortunate Princess Elizabeth in the same capacity.

The approach of old age obliged him to quit Versailles, and to live in Paris, the air of which, less sharp, was better adapted to his constitution. The last work of Goldoni was *The Volponi*, written after his retirement from court; from which time he bade a lasting adieu to writing. Unfortunately for him, he lived to see his pensions cut off at the revolution, like others, and he spent his last days in poverty and distress. He died in 1792, at a crisis when, according to the expression of a deputy in the Convention, the French nation was ready to repay him every debt of gratitude.

Goldoni is on a par with the greatest comic poets of modern times, with regard to dramatic talents, and is thought superior to them all with regard to the fertility of his genius. His works were printed at Leghorn in 1788—91, in 31 vols. 8vo. He has been generally called the Moliere of Italy; and Voltaire, in one of his letters to Marquis Albergati, styles him *The Painter of Nature*. Goldoni is one of those authors whose writings will be relished in the most remote countries, and by the latest posterity.

GOOD-HOPE, or CAPE OF GOOD HOPE, was taken by the British on 17th August 1795 with very little difficulty. At this we need not be much surprised, if to the discontent which must have prevailed among the planters and townsmen with the new order of things, be added the manners of the people. M. Vaillant, who was at the Cape during the last war, when the garrison expected to be every day attacked by a British Squadron, and when the people were not absolutely disgusted with their own government, represents them, however, as rendered so completely frivolous by imitating the manners of their French allies, that, though the place was strongly fortified, it could hardly be expected to hold out long against a vigorous and well conducted siege.

“The females of the Cape (says he), when I saw them for the first time, had really excited my astonishment by their dress and their elegance; but I admired in them, above all, that modesty and reserve peculiar to the Dutch manners, which nothing as yet had corrupted.

“In the course of six months, a great change had taken place. It was no longer the French modes that they copied; it was a caricature of the French. Plumes, feathers, ribbons, and tawdry ornaments heaped together, without taste, on every head, gave to the prettiest figures a grotesque air, which often provoked a smile when they appeared. This mania had extended to

the neighbouring plantations, where the women could scarcely be known. A mode of dress entirely new was everywhere introduced; but so fantastical, that it would have been difficult to determine from what country it had been imported.”

At that time a French and a Swiss regiment were in the garrison; and though the town was occupied only with warlike preparations, and though an attack from the British fleet was every moment expected, the French officers had already introduced a taste for pleasure. Employed in the morning at their exercise, the French soldiers in the evening acted plays. A part of the barracks was transformed into a theatre; and as women capable of performing female characters could not be found in the town, they assigned these parts to some of their comrades, whose youth, delicate features, and freshness of complexion, seemed best calculated to favour the deception. These heroines, of a new kind, heightened the curiosity of the spectators, and rendered the entertainment still more lively and interesting.

To add to the general pleasure, ladies of the first rank considered it as incumbent on them to lend to the military actors and actresses, their laces, jewels, rich dresses, and most valuable ornaments. But some of them had cause to repent of their condescension; for it happened more than once that the Countess of Al-maviva having left in pledge at the sutling-house her borrowed decorations, the owner, to recover them, was obliged to discharge not only the bill due for brandy and tobacco, but all the other debts of the heroine.

During the intoxication and giddiness occasioned by these amusements, Love also did not fail to act his part; and certain little intrigues were, from time to time, brought to light, which gave employment to the tongue of scandal, and introduced unhappiness into families. Hymen, it is true, amidst these adventures, sometimes intervened to repair the follies of his brother; and many marriages, which restored every thing to order, were the result of his negotiations; but the complaints, though stifled, did not less exist. The watchfulness of the mother was alert. The husband, by so much the more secretly irritated as he saw himself obliged to conceal his jealousy, cursed in his heart both actors and theatre; while the matronly part of the community, less on the reserve, declaimed with bitterness against the licentiousness that prevailed, which they wholly imputed to this mode of theatrical entertainment. At last, to the great mortification of the young, but to the high satisfaction of the old women and husbands, the theatre was on a sudden shut up. The cause that affected this was altogether foreign to the complaints that were made, and of a nature that it was impossible to foresee. Two of the French actors, who, it must be remembered, were officers in the army, thought proper to imitate the paper money of the company, and to put their forged notes in circulation. The forgery was detected, and traced to its authors; the two theatrical heroes were banished from the Cape; and the company, ashamed of the adventure, dared neither seek others to supply the vacant places, nor resume their stage entertainments.

Intoxicating as were these pleasures, government meanwhile had not been inattentive to the danger which threatened the colony. As they daily expected

Good Hope to be attacked by the British fleet, they had increased the means of defence, and ordered different works and new fortifications to be constructed.

At first, the business was carried on with activity and ardour; because the inhabitants, instigated by their private interest, which was then considered as involved with that of the public, had voluntarily offered their services, and mingled with the workmen. Young and old, soldiers and magistrates, sailors and planters, all solicited the honour of co-operating for the general good and common safety. To behold this heterogeneous multitude—some loaded with pick-axes, and some with spades, or other similar implements—marching out in the morning from the town, and proceeding in high spirits to the new fortifications, was a sight truly admirable.

But this patriotic fervour was of no long continuance. Under pretence of sparing their strength, and that they might not weary themselves to no purpose, they soon caused their slaves to follow them with the tools and instruments. In a little time they contented themselves with sending their slaves only; and at last these substitutes themselves, in imitation of their masters, or perhaps by their secret orders, gave over going also. Their enthusiasm, in short, from the first moment of its breaking out till the period when it was thus entirely cooled, had been the affair of something less than a fortnight.

This taste for frivolity which, almost twenty years ago, was introduced among the Dutch in Cape-town by their good friends the French, spread rapidly thro' the planters, who are thus described by M. Vaillant, who certainly had the best opportunities of knowing them.

The planters of the Cape may be divided into three classes; those who reside in the vicinity of the Cape, within a distance of five or six leagues; those who live farther off in the interior parts of the colony; and lastly, those who, more distant still, are found at the extremity of the frontiers among the Hottentots.

The first, who are opulent proprietors, and have handsome country houses, may be likened to what was formerly called in France *petits seigneurs terriers*, and differ extremely from the other planters in ease and luxury, and particularly in their manners, which are haughty and disdainful. Such is the result of wealth. The second, simple, kind, hospitable, are cultivators, who live upon the fruits of their labour. Here we have an example of the good effects of mediocrity. The last, poor enough, yet too indolent to derive subsistence from the soil, have no other resource than the produce of some cattle, which they feed as they can. Like the Beduin Arabs, they think much of the trouble of driving them from canton to canton, and from one pasturage to another. This wandering life prevents them from building any settled habitations. When their flocks oblige them to sojourn for a while in the same place, they construct, in haste, a rude kind of hut, which they cover with mats, after the manner of the Hottentots, whose customs they have adopted, and from whom they in no respect differ, but in their complexion and features. And here the evil is, that there is no precise situation in social life to which these miserable beings belong.

These sluggish tribes are held in horror by their in-

dustrious neighbours, who dread their approach, and remove as far from them as they can; because, having no property of their own, they steal without scruple that of others, and, when in want of pasturage for their cattle, conduct them secretly to the first cultivated piece of ground that comes in their way. They flatter themselves they shall not be discovered, and they remain till every thing is devoured. If detected in their thefts, squabbles and contentions ensue, and afterwards a suit at law, in which recourse is had to the magistrate, and which commonly terminates in making three men enemies, the robber, the person robbed, and the judge.

Nothing can be so mean and cringing as the conduct of the first description of planters, when they have any thing to transact with the principal officers of the company, who may have some influence over their lot; and nothing so absurdly vain and so superlatively insolent as their behaviour to persons from whom they have nothing to hope and nothing to fear. Proud of their wealth, spoiled by residing near a town, from whence they have imbibed only a luxury that has corrupted, and vices that have degraded them, it is particularly towards strangers that they exercise their surly and pitiful arrogance. Though neighbours to the planters who inhabit the interior of the country, you must not suppose they regard them as brethren; on the contrary, in the true spirit of contempt, they have given them the name of *Rauw-boer*, a word answering to the lowest description of clown. Accordingly, when these honest cultivators come to the town upon any kind of business, they never stop by the way at the houses of the gentry of whom we are speaking; they know too well the insulting manner in which they would be received. One might suppose them to be two inimical nations always at war, and of whom some individuals only met at distant intervals, upon business that related to their mutual interests.

What is the more disgusting in the insolence of these Africans is, that the majority of them are descended from that corrupt race of men, taken from prisons and hospitals, whom the Dutch company, desirous of forming a settlement at the Cape, sent thither to begin, at their risk and peril, the population of the country. This shameful emigration, of which the period is not so remote but that many circumstances of it are remembered, ought to render particularly modest those who are in the most distant manner related to it. On the contrary, it is this very idea that most contributes to their arrogance; as if they flattered themselves that, under the guise of supercilious manners, they could hide the abjectness of their origin. If a stranger arrives at the Cape with the design of remaining and settling there, they conceive him to be driven from his country by the same wretched circumstances which formerly banished their fathers, and they treat him with the most sovereign contempt.

This melancholy failing is the more to be lamented as the contagion has spread through almost every residence about the Cape, which is in reality a very charming canton. Embellished by cultivation, by its numerous vineyards and pleasant country houses, it everywhere exhibits so varied and delicious a prospect, that, were it occupied by other inhabitants, it would excite no sensations but those of pleasure.

Good Hope As we advance into the country, the planters are a sort of farmers; and constitute, by their manners, customs, and occupations, a class by themselves, perfectly distinct from what we have been describing. Situated farther from the Cape, and, of consequence, not having the same opportunities for disposing of their commodities, they are less rich than the first. We see among them none of those agreeable country houses, which, placed at different distances from the town, embellish the country as we pass, and afford such charming prospects. Their habitation, which is about the size of a large coach-house, is covered with thatch, and divided into three rooms by means of two partitions, which reach only to a certain height. The middle apartment, in which is the entrance to the house, serves at once both as a parlour and eating-room. It is there that the family reside during the day, and that they receive their tea and other visitors. Of the two other rooms, one forms a chamber for the male children, and the other for the females, with the father and mother. At the back of the middle apartment is a farther room serving for a kitchen. The rest of the building consists of bars and stables.

Such is the distribution which is generally followed in the interior plantations of the colony; but nearer to the frontiers, where there does not prevail the same ease of circumstances, the habitations are much less commodious. They are merely a barn, consisting of a single room, without any division, in which the whole family live together, without separating either day or night. They sleep upon sheep skins, which serve them also for covering.

The dress of these planters is simple and rustic. That of the men consists of a check shirt, a waistcoat with sleeves, a large pair of trowsers, and a hat half unlooped. The women have a petticoat, a jacket fitted to their shape, and a little round bonnet of muslin. Unless upon extraordinary occasions, neither sex wear stockings. During a part of the year, the women even walk with their feet quite naked. The occupations of the men require that theirs should have some covering; and this covering they make from a piece of the hide of an ox, applied and shaped to the foot soon after the animal is killed, and while the hide is yet fresh. These sandals are the only article of their dress which they make themselves; the rest is the business of the women, who cut out and prepare their whole wardrobe. Though the equipment we have mentioned constitute the every-day dress of the planter, he has, however, a coat of handsome blue cloth, which he wears upon days of gala and ceremony. He has then also stockings and shoes, and is dressed exactly like an European. But this finery never makes its appearance but when he goes to the Cape; and then, indeed, is not put on till he arrives at the entrance of the town.

It is commonly in these journeys that they purchase such things as they may want to refit their wardrobe. There is, at the Cape, as well as in Paris and London, a species of old-clothes-men, who deal in commodities of this sort; and who, from their enormous profits, and the extortion they practise, they have obtained the name of *Cape Smouse*, or Cape Jews. These traffickers contrive at all times to sell their goods at a dear rate; but they vary their price in proportion as their stock is great or small: of course they bear no fixed

price; and the planter who comes from the desert, and *Good Hope* who can understand but little of this fluctuation, is sure to be duped.

On the other hand, the regular shopkeeper, who knows the probity of these farmers, and how punctual they are in the payment of their debts, exerts every effort to prevail on them to open an account with him. He tempts them by the pretended cheap price and excellent quality of his stuffs, and offers to remit the payment till their next journey in the following year. It is seldom that these people, simple and unexperienced as they are, perceive the craft that is presented to them under this guise of kindness and civility. If they suffer themselves to be prevailed upon, they are shackled for life. Upon their return, there are new purchases to be made upon the same conditions; and thus, year after year, always in debt, always buying without prompt payment, they become the prey of an extortioner, who raises to himself a fortune out of their weakness.

It is true, these buyers, after being thus duped at the Cape, commonly return home only to make dupes of others. The cunning that has been employed to deceive them, they employ in their turn to tempt the Hottentots who are in their service. The remnants of stuff, or the frippery garments which they bring back, are sold to these unfortunate servants with so great a profit, that commonly the wages of a year are inadequate to the payment; and they find themselves, like their masters, in debt for the year that is to come. In the end, therefore, it is the poor Hottentot that pays for the extortion at the Cape.

Custom has rendered the planters insensible to the want of fruit and pulse, though the soil is admirably adapted to the cultivation of both. The facility with which they rear their cattle makes up for this privation, as their flocks afford them plenty of provision. The chief food is mutton; and their tables are loaded with such profusion as to disgust one at the sight.

From this mode of living, cattle are in the colonies, as in other places, not only a useful object, but an article of the first necessity. The planter undertakes himself the care of watching over his flocks. Every evening, when they return from the field, he stands at his door, with a stick in his hand, and counts them over one by one, in order to be sure that none of them are missing.

People who have no other employment than a little agriculture, and the superintendance of a flock, must have long intervals of idleness. It is thus with the planters, particularly those who live in the interior parts of the country, and who being unable, on account of their distance from the Cape, to dispose of their corn, never raise more than is sufficient for their own consumption. From the profound inaction in which they live, one would suppose their supreme felicity to consist in doing nothing. They sometimes, however, visit each other; and upon these occasions the day is spent in smoking, and drinking tea, and in telling, or listening to tales of romance, that are equal neither in merit nor morality to the story of Blue-beard.

As every man always carries with him, wherever he goes, both a pipe, and a tobacco-pouch made of the skin of the sea-calf, he is sure in these visits to have one source of amusement. When any one of the company

Good Hope
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Goniometry.

is desirous of lighting his pipe, he takes out his pouch, and, having filled, passes it to the rest. This is a civility that is never omitted. However numerous may be the party, every body smokes: the consequence of which is a cloud, that, rising at first to the upper part of the room, increases, by degrees, till it fills the whole house, and becomes at last so thick that it is impossible for the smokers to see one another.

When a stranger travelling through the country is received by the master of a house, he instantly becomes a member of the family. Accustomed to a domestic life, the planters delight in the ties of affinity, and consider in the light of a relative every person whom they love. Upon entering a house, the form of salutation is, to shake hands first with the master, and then with every male person in the company arrived at years of maturity. If there happens to be any one whom we do not like, the hand is refused to him; and this refusal, of so common a testimony of friendship, is looked upon as a formal declaration that the visitor considers him as his enemy. It is not the same with the females in the company. They are all embraced one after another; and to make an exception would be a signal affront. Old or young, all must be kissed. It is a beneficence with the duties attached to it.

At whatever time of the day you enter the house of a planter, you are sure to find the kettle and tea-things upon the table. This practice is universal. The inhabitants never drink pure water. If a stranger presents himself, it is tea they offer him for refreshment. This is their common liquor in the interval of meals, and in one season of the year, when it often happens that they have neither beer nor wine, is their only beverage.

If a stranger arrives at dinner-time before the cloth is taken away, he shakes hands, embraces, and immediately seats himself at the table. If he wishes to pass the night, he stays without ceremony, smokes, drinks tea, asks the news, gives them all he knows in his turn; and the next day, the kissing and shaking hands being repeated, he goes on his way, to perform elsewhere the same ceremony. To offer money on these occasions would be regarded as an insult.

These particulars of a people, whose condition it is to be hoped that the generosity of the British character, and the mildness of the British government, will gradually meliorate, cannot but be acceptable to many of our readers. We shall, therefore, make no apology for the length of this article.

GOMASHTEH, in the language of Bengal, one cent.

GONIOMETRY, a method of measuring angles, so called by M. de Lagny, who gave several papers on this method in the Memoirs of the Royal Acad. anno 1724, 1725, 1729. M. de Lagny's method of goniometry consists in measuring the angles with a pair of compasses, and that without any scale whatever, except an undivided semicircle. Thus, having any angle drawn upon paper to be measured, produce one of the sides of the angle backwards behind the angular point; then with a pair of fine compasses describe a pretty large semicircle from the angular point as a centre, cutting the sides of the proposed angle, which will intercept a part of the semicircle. Take then this intercepted part very exactly between the points of the compasses, and turn them successively over upon the arc of the semi-

circle, to find how often it is contained in it, after which there is commonly some remainder: then take this remainder in the compasses, and, in like manner, find how often it is contained in the last of the integral parts of the first arc, with again some remainder: find, in like manner, how often this last remainder is contained in the former; and so on continually, till the remainder become too small to be taken and applied as a measure. By this means he obtains a series of quotients, or fractional parts, one of another, which being properly reduced into one fraction, give the ratio of the first arc to the semicircle, or of the proposed angle to two right angles, or 180 degrees, and consequently that angle itself in degrees and minutes.

We have given this account of goniometry from Dr Hutton, and frankly acknowledge that we had never thought of it till we perused his excellent Dictionary of Mathematics and Philosophy. To have omitted the method when pointed out to us would have been wrong; though we mistake much if mathematicians in general will not look upon it as a method of very little value.

GOTHIC ARCHITECTURE. See *Gothic ARCHITECTURE* in this *Suppl.* and *ROOF*, *Encycl.*

GOUVERNANTE, the Spanish name of a plant which the Indians of California use in decoction as a sudorific drink for the cure of the venereal disease. It is thus described in the third volume (English translation) of Perouse's Voyage round the World.

Calyx quadrifid, egg-shaped, of the same size with the corolla; placed beneath the fruit, deciduous. Corolla polypetalous; petals four, small, entire, egg-shaped, fixed upon the receptacle. Stamina, eight, fixed to the receptacle, of the same length as the corolla: threads channelled, concave on the one side, and convex on the other; wings veiled, antheræ simple. Pistil, germ oblong, covered, with five angles, and five cells; seeds oblong; pericarpium covered with fine hairs.

This plant is a shrub of middle size; the branches are angular and knotty, and covered with an adhesive varnish; the lateral branches are alternate, and placed very near to each other: the leaves are small, petiolated, bilobed, opposite, smooth on the upper side, the under side indistinctly veined; the blossoms are axillary, sometimes terminating, pedunculated, solitary, but sometimes in pairs.

From this description, the gouvernante appears to be a new species of *daphne*.

GRAVIMETER, the name given by citizen Guyton (Morveau) to an instrument of glass, constructed in all respects on the principle of Nicholson's Hydrometer, described in the article HYDROSTATICS, n^o 18. *Encycl.* It is therefore needless to give a description of this instrument here; as every artist in glass, who has seen Nicholson's hydrometer, or understands our description of it, may construct the gravimeter of Morveau; and every man who has made himself master of our article *SPECIFIC Gravity*, may apply the gravimeter to every purpose to which it is applicable. It may just be proper to observe, that Morveau, having at first loaded the small scale or basin G (Plate 24^o, fig. 9. *Encycl.*) with a bulb of glass containing a sufficient quantity of mercury, found it expedient afterwards to substitute in the place of this bulb a small mass of solid glass, brought to the proper form and weight by grinding. For a minute account of this instrument, if any

Gothic
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Gravimeter

Green.

of our readers can be supposed to require a minute account of it, we must refer to the third number of Nicholson's *Journal of Philosophy, Chemistry, and the Arts*.

GREEN, though one of the seven original or prismatic colours, is among dyers a compound of blue and yellow. Of the European methods of dyeing green, and of the principles on which these methods are founded, a sufficient account will be found in the *Encyclopædia*, under the articles *Colour-Making* and *DYEING*, and, in this *Supplement*, under *Animal and Vegetable SUBSTANCES*; but it may be worth while, in this place, to insert the method practised at Astracan, in giving to cotton yarn that beautiful green colour for which the oriental cotton is so justly admired.

The principal dye is the blue, which is employed both for cotton and silk. To prepare it, the indigo or blue dye-stuff is finely pounded, and dissolved in water by a gentle heat in large earthen jars, seven of which stand in brick-work over the fire-place, at the distance of about an ell and a half from each other. About two pounds are put into each vessel. Five pounds of soda finely pounded, together with two pounds of pure lime and one pound of clarified honey, are added to each; when these ingredients have been well mixed, the fire is strengthened; and when the whole begins to boil, the dye is stirred carefully round in all the vessels, that every thing may be completely dissolved and mixed. After the first boiling the fire is slackened, and the dye is suffered to stand over a gentle heat, while it is continually stirred round: this is continued even after the furnace is cooled, till a thick scum arises in the neck of each jar, and soon after disappears. The dye is then allowed to stand two days, until the whole is incorporated, and the dye thickens.

The dyers assert, that with this dye they can produce three shades of blue, and that, as the dyeing particles gradually diminish, they can dye also a green colour by the addition of yellow.

When a manufacturer gives cotton yarn to a blue dyer, he first boils it at home in a ley of soda (*kalkar*), then dries it, washes it, and dries it again. The blue dyer lays this yarn to steep in pure water, presses out the superfluous water with the hands, and then immediately begins to dip it in the blue jar, often wringing it till it is completely penetrated by the dye. This first tint is generally given to yarn in such jars as have had their colouring matter partly exhausted. It is then dried, rinsed, and again dried; after which, it is put into the fresh blue dye, properly saturated; and, after the colour has been sufficiently heightened, it is dried for the last time.

For a yellow dye, the dyers of Astracan employ partly saw-wort, brought from Russia, and partly the leaves of the *kislar belge* or *sumach*. The process is as follows: The yarn is first boiled for an hour in a strong ley of soda; it is then dried, afterwards rinsed and laid wet to steep for twelve hours in a solution of alum with warm water. When it has been dried in the air, it is laid to soak several times in troughs with the dye which has been boiled thick in kettles from the above-mentioned plants, till it has acquired the wished-for colour, care being taken to dry it each time it is soaked. It is then rinsed in running water, and dried for the last time.

Gregory.

On this yellow colour a green is often dyed. After the yarn has been dyed yellow, it is given out to the blue dyer, who immediately dips it in the blue jars, the dye of which has been already partly exhausted; and if the green colour is not then sufficiently high, the operation is repeated, the yarn being dried each time. See *Neue Nordische Beytrage*, by Professor Pallas; or *Philosophical Magazine*, n^o 2.

GREGORY (David), was a son of the Rev. John Gregory, minister of Drumoak, in the county of Aberdeen, and elder brother to Mr James Gregory, the inventor of the most common reflecting telescope. He was born about the year 1627 or 1628; and though he possessed all the genius of the other branches of his family, he was educated by his father for trade, and served an apprenticeship to a mercantile house in Holland. Having a stronger passion, however, for knowledge than for money, he abandoned trade in 1655; and returning to his own country, he succeeded, upon the death of an elder brother, to the estate of Kinar-die, situated about forty miles north from Aberdeen, where he lived many years, and where thirty-two children were born to him by two wives. Of these, three sons made a conspicuous figure in the republic of letters, being all professors of mathematics at the same time in three of the British universities, viz. David at Oxford, James at Edinburgh, and Charles at St Andrews.

Mr Gregory, the subject of this memoir, while he lived at Kinar-die, was a jest among the neighbouring gentlemen for his ignorance of what was doing about his own farm, but an oracle in matters of learning and philosophy, and particularly in medicine, which he had studied for his amusement, and began to practise among his poor neighbours. He acquired such a reputation in that science, that he was employed by the nobility and gentlemen of that county, but took no fees. His hours of study were singular. Being much occupied through the day with those who applied to him as a physician, he went early to bed, rose about two or three in the morning, and, after applying to his studies for some hours, went to bed again and slept an hour or two before breakfast.

He was the first man in that country who had a barometer; and having paid great attention to the changes in it, and the corresponding changes in the weather, he was once in danger of being tried by the presbytery for witchcraft or conjuration. A deputation of that body waited upon him to enquire into the ground of certain reports that had come to their ears; but he satisfied them so far as to prevent the prosecution of a man known to be so extensively useful by his knowledge of medicine.

About the beginning of this century he removed with his family to Aberdeen, and in the time of Queen Anne's war employed his thoughts upon an improvement in artillery, in order to make the shot of great guns more destructive to the enemy, and executed a model of the engine he had conceived. Dr Reid informs us, that he conversed with a clock-maker in Aberdeen who had been employed in making this model; but having made many different pieces by direction without knowing their intention, or how they were to be put together, he could give no account of the whole. After making some experiments with this model,

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del, which satisfied him, the old gentleman was so sanguine in the hope of being useful to the allies in the war against France, that he set about preparing a field equipage with a view to make a campaign in Flanders, and in the mean time sent his model to his son the Savilian professor, that he might have his and Sir Isaac Newton's opinion of it. His son shewed it to Newton, without letting him know that his own father was the inventor. Sir Isaac was much displeas'd with it, saying, that if it had tended as much to the preservation of mankind as to their destruction, the inventor would have deserved a great reward; but as it was contriv'd solely for destruction, and would soon be known by the enemy, he rather deserv'd to be punished, and urg'd the professor very strongly to destroy it, and if possible to suppress the invention. It is probable the professor followed this advice. He died soon after, and the model was never found.

If this be a just account of the matter, and Dr Reid's veracity is unquestionable, we cannot help thinking that Newton's usual sagacity had, on that occasion, forsaken him. Were the implements of war much more destructive than they are, it by no means follows that more men would be killed in battle than at present. Muskets and cannons are surely more destructive weapons than javelins and bows and arrows; and yet it is a well known fact, that since the invention of gunpowder battles are not half so bloody as they were before that period. The opposite armies now seldom come to close quarters, a few rounds of musketry and artillery commonly decide the fate of the day; and had Mr Gregory's improvement been carried into effect, still fewer rounds would have decided it than at present, and the carnage would consequently have been less.

When the rebellion broke out in 1715, the old gentleman went a second time to Holland, and returned when it was over to Aberdeen, where he died about 1720, aged 93, leaving behind him a history of his own time and country, which was never published.

GREGORY (Dr David). In addition to the account given in the *Encyclopædia* of this eminent mathematician, it may be proper to add, that he was a most intimate and confidential friend of Sir Isaac Newton, and was intrusted with a manuscript copy of the *Principia*, for the purpose of making observations on it. Of these Newton availed himself in the second edition, they having come too late for his first publication, which was exceedingly hurried by Dr Halley, from fears that Newton's backwardness would not let it appear at all. There is a complete copy of these observations preserved in the library of the university of Edinburgh, presented to it by Dr James Gregory, the present professor of the practice of medicine. These contain many sublime mathematical discussions, many valuable commentaries on the *Principia*, and many interesting anecdotes. There are in it some paragraphs in the hand-writing of Huyghens relative to his Theory of Light. It would appear that this work of confidential friendship was the foundation of that system of physical and mathematical astronomy which has rais'd Dr Gregory to great eminence in the republic of letters.

GRINDING, in Cutlery, a well-known operation,

by which edge-tools are sharpened. As commonly practis'd, the grinding of tools is attended with great inconvenience, arising from the production or development of heat by friction. The fact of sparks flying from a dry grindstone when a piece of iron or steel is applied to its surface during the rotation, has been seen by every one. The heat produced during this process is such that the steel very soon becomes ignited, and hard tools are very frequently softened and spoiled, for want of care during the grinding. When a cylindrical stone is partly immersed in a trough of water, the rotation must be moderate and the work slow, otherwise the water would soon be thrown off by the centrifugal force; and when this fluid is applied by a cock from above, the quantity is too small to preserve the requisite low temperature. It is even found, that the point of a hard tool, ground under a considerable mass of water, will be softened, if it be not held so as to meet the stream; sparks being frequently afforded even under the water.

To find a remedy for this, Mr Nicholson was led, by some accounts which he received of German cutlery, to make the following experiment. He procur'd a Newcastle grindstone of a fine grit and ten inches in diameter, and also a block of mahogany to be used with emery on its face. Both the stone and the wooden block were mounted on an axis, to be occasionally applied between the centres of a strong lathe. In this situation both were turned truly cylindrical, and of the same diameter. The face of the wood was grooved obliquely in opposite directions, to afford a lodgement for the emery. The face of the stone was left smooth, and there was a trough of proper size applied beneath the stone to hold water. The grindstone was then used with water, and the wooden cylinder was faced with emery and oil. The instrument ground was a file, out of which it was propos'd to grind all the teeth. The rotation was produced by the mechanism of the lathe; the velocity being such as to turn the grinding apparatus about five revolutions in a second. The stone operated but slowly, and the water from the trough was soon exhausted, with inconvenience to the workman, who could scarcely be defended from it but by slackening the velocity. The emery cylinder cut rather faster. But notwithstanding the friction was made to operate successively and by quick changes on the whole surface of the file, it soon became too much heated to be held with any convenience; and when a cloth was used to defend the hand, the work not only became awkward, but the heat increased to such a degree that the oil began to be decompos'd, and emitted an empyreumatic smell. The stone was then suffer'd to dry, and the file tried upon its face. It almost immediately became blue, and soon afterwards red-hot. Both the cylinders were then covered with tallow, by applying the end of a candle to each while revolving, and emery was sprinkled upon the cylinder of wood. The same tool was then applied to the grindstone in rapid motion. At the first instant the friction was scarcely perceptible; but very speedily afterwards the zone of tallow press'd by the tool became fused, and the stone cut very fast. The tool was scarcely at all heated for a long time; and when it began to feel warm, its temperature was immediately lowered by removing

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Grofe. moving it to a new zone of the cylinder. The same effect took place when the experiment was repeated with the wooden cylinder.

It is not difficult to explain this by the modern doctrine of heat. When oil was used upon the wooden cylinder, the heat developed by the friction was employed in raising the temperature of the tool and of the fluid oil: but when tallow was substituted instead of the oil, the greatest part of the heat was employed in fusing this consistent body. From the increased capacity of the tallow, when melted, this heat was absorbed, and became latent, instead of being employed to raise the temperature: and whenever, by continuing the process, the tallow already melted began to grow hot, together with the tool, it was easy to reduce the temperature again by employing the heat on another zone of consistent tallow. He used these two cylinders, with much satisfaction, in a considerable quantity of work.

This promises to be a valuable discovery; and the public is obliged to the ingenious author of the Philosophical Journal for being at so much pains on this, as well as on other occasions, to render his science subservient to the useful arts.

GROSE (Francis, Esq; F.A.S.) was born, we believe, in 1731. He was the son of Mr Francis Grose of Richmond, jeweller, who filled up the coronation crown of George II. and died 1769. By his father he was left an independent fortune, which he was not of a disposition to add to, or even to preserve. He early entered into the Surrey militia, of which he became adjutant and paymaster; but so much had dissipation taken possession of him, that in a situation which above all others required attention, he was so careless as to have for some time (as he used pleasantly to tell) only two books of accounts, viz. his right and left hand pockets. In the one he received, and from the other paid; and this too with a want of circumspection which may be readily supposed from such a mode of book-keeping. His losses on this occasion roused his latent talents. With a good classical education he united a fine taste for drawing; and encouraged by his friends, as well as prompted by his situation, he undertook the work from which he derived both profit and reputation; we mean, his Views of Antiquities in England and Wales, which he first began to publish in numbers in the year 1773, and finished in the year 1776. The next year he added two more volumes to his English Views, in which he included the islands of Guernsey and Jersey, which were completed in 1787. This work answered his most sanguine expectations; and, from the time he began it to the end of his life, he continued without intermission to publish various works (a list of which we subjoin), generally to the advantage of his literary reputation, and almost always to the benefit of his finances. His wit and good humour were the abundant source of satisfaction to himself, and entertainment to his friends. He visited almost every part of the kingdom, and was well received wherever he went. In the summer of 1789 he set out on a tour in Scotland; the result of which he began to communicate to the public in 1790 in numbers. Before he had concluded this work, he proceeded to Ireland, intending to furnish that kingdom with views and descriptions of her antiquities, in

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the same manner he had executed those of Great Britain; but soon after his arrival in Dublin, being at the house of Mr Horne there, he suddenly was seized at table with an apoplectic fit, on the 6th May 1791, and died immediately. He was interred in Dublin.

His literary history (says a friend), respectable as it is, was exceeded by his good humour, conviviality, and friendship. Living much abroad, and in the best company at home, he had the easiest habits of adapting himself to all tempers; and, being a man of general knowledge, perpetually drew out some conversation that was either useful to himself or agreeable to the party. He could observe upon most things with precision and judgment; but his natural tendency was to humour, in which he excelled both by the selection of anecdotes and his manner of telling them: it may be said, too, that his figure rather assisted him, which was in fact the very title-page to a joke. He had neither the pride nor malignity of authorship: he felt the independency of his own talents, and was satisfied with them, without degrading others. His friendships were of the same cast; constant and sincere, overlooking some faults, and seeking out greater virtues. He had a good heart; and, abating those little indiscretions natural to most men, could do no wrong."

He married at Canterbury, and resided there some years, much beloved and respected for his wit and vivacity; "which (another friend observes), though he possessed in an extreme degree, was but little tinged with the caustic spirit so prevalent among spirits of that class. His humour was of that nature which exhilarates and enlivens, without leaving behind it a sting; and though perhaps none possessed more than himself the faculty of "setting the table in a roar," it was never at the expence of virtue or good manners. Of him indeed may be said in the words of Shakespeare,

————— a merrier man,
Within the limits of becoming mirth,
I never spent an hour's talk withal;
His eye begets occasion for his wit;
And every object that the one doth catch,
The other turns to a mirth-moving jest.

"Of the most careless, open, and artless disposition, he was often (particularly in the early part of his life) the prey of the designing; and has more than once (it is believed) embarrassed himself by too implicit confidence in the probity of others. A tale of distress never failed to draw commiseration from his heart; and often has the tear been discovered gliding down that cheek which a moment before was flushed with jocularities."

He was father of Daniel Grose, Esq; captain of the royal regiment of artillery (who, after several campaigns in America, was appointed in 1790 deputy governor of the new settlement at Botany Bay), and some other children.

His works are as follow:

1. The Antiquities of England and Wales, 8 vols. 4to and 8vo.
2. The Antiquities of Scotland, 2 vols. 4to and 8vo.
3. The Antiquities of Ireland, 2 vols. 4to and 8vo.
4. A Treatise on ancient Armour and Weapons, 4to, 1785.
5. A Classical Dictionary of the Vulgar Tongue, 8vo, 1785.
6. Military Antiquities; being a History of the English Army from

Guerite,
Guillotine.

the Conquest to the present time, 2 vols 4to, 1786, 1788. 7. The History of Dover Castle, by the Rev. William Danell, 4to, 1786. 8. A Provincial Glossary, with a Collection of local Proverbs and popular Superstitions, 8vo, 1788. 9. Rules for drawing Caricatures, 8vo, 1788. 10. Supplement to the Treatise on Ancient Armour and Weapons, 4to, 1789. 11. A Guide to Health, Beauty, Honour, and Riches; being a collection of humorous Advertisements, pointing out the Means to obtain those blessings; with a suitable introductory Preface, 8vo. 12. The Olio; being a Collection of Essays in 8vo, 1793.

GUERITE, in Fortification, a centry-box; being a small tower of wood, or stone, usually placed on the point of a bastion, or on the angles of the shoulder, to hold a centinel, who is to take care of the ditch, and watch against a surprize.

GUILLOTINE, a new term introduced into the languages of Europe by the mournful effects of fanaticism in the holy cause of liberty. Our readers are not ignorant that this is the name given by the National Assembly of France to the engine of decapitation, which those usurpers of the legislative authority decreed to be the sole punishment of those condemned to death for their crimes. This decree was issued on March 20th 1792.

We do not imagine that the world will derive much useful instruction from a minute description of this terrible instrument of public justice; and therefore content ourselves with giving two figures of it, sufficiently expressive of its construction. It is only the revival of an instrument used in former times. The earliest accounts that we have of it is, that it was used in the barony of Halyfax in Yorkshire. It was also set up in Scotland; but we have no certain information that it has ever been used; and it is still shewn as a sort of curiosity by the name of the *Mayden*. See MAIDEN, *Encycl.*

Eratosthenes could not think of a better way of handing down his name to future ages than by burning the temple of Diana at Ephesus; Dr Guillotin, physician at Lyons, and member of the self-named National Assembly of France, thought himself honoured by the decree which associated his name with this instrument of popular vengeance. It was indeed proposed by him as an instrument of mercy, in a studied harangue, filled with that sentimental slang of philanthropy, which costs so little, promises so much, and has now corrupted all the languages of Europe. His invention is indeed one of the most expensive specimens of Gallic philanthropy, whose tender mercies are cruel; and was accordingly received with loud applauses, both from the house and from the galleries. To proceed, however, with imposing dignity, it was referred to the consideration of a committee, with injunctions to ask the opinion of able surgeons of its efficiency. Mr Louis, a celebrated surgeon of Paris, declared it well fitted for the task, in a long pedantic dissertation; in which he takes occasion to deliver, with academic coldness, a theory of the operation of cutting instruments; and says that he had examined the edge of the guillotine, and other such instruments, with a microscope, and had discovered that the finest edges were toothed like a saw. M. Guillotin, he said, had therefore with great judgment made the axe of his engine of death with a sloping edge, by which means *il glissoit d'une façon infiniment plus douce.*

This dissertation was so much to the taste of the humane legislature, that they rewarded Mr Louis with 2000 livres, and published it in the Paris Journals. As to the inventor, he reaped all the benefit from it which he so kindly intended for the nation, by the trial of it on his own person, when he fell under the displeasure of Robespierre.

We acknowledge, that in as far as this instrument lessens the duration of the horrid conflict with the king of terrors, and probably diminishes the corporeal sufferance, it may be called merciful (alas! the day!); but we question much, whether the dreadful agitation of soul is not rather increased by the long train of preparatory operations. The hands of the convict are tied behind his back: he is then stretched along on his face on a strong plank, and his precise position adjusted to the instrument. When fastened to the plank, it is pushed forward into its place under the fatal edge, his neck adjusted to the block, and a basket placed just before his eyes (for the face of Louis XVI. was not covered) to receive his head. This must employ a good deal of time, and every moment is terrible.

The construction has received many alterations and refinements; and has at last been made so compendious and portable, as to become part of the travelling equipage of a commissioner from the National Assembly, sent on a provincial or special visitation. Thus did the sovereign people become terrible in majesty. So sensible was the assembly of the advantages of this awful impression, or so intoxicated with the enjoyment of irresistible power, that they have thought their coins ornamented by this attribute of their supremacy: and as Jupiter is distinguished by his thunderbolt, so the majesty of the people is distinguished by the no less fatal axe. We have seen a piece of ten sous, struck at Mentz in 1793, and issued as current money, at the very time that they were planting the tree of liberty in that illuminated city by the hands of Custine and his troops. The device is the fasces and axe of ancient Rome, crowned with a red cap, and surrounded by a laurel wreath. The inscription is, *Republique Française, 1793, an. 2d.* Fully impressed with the same sentiments, Lequinio, the sentimental novellist of France, whom Mercier compares with the tender, the heart-touching Sterne—Lequinio, now commissioner, sent by the National Assembly to regenerate Normandy and Brittany, writes to his masters, that “he is very successful in conversions from superstition to sound reason.” He opposes to the Bible and the relics of the saints the constitution and the guillotine. “And you would wonder (says he) at my success—The wise (but they are few) give up their prejudices at once; but the multitude, the stupid worshippers of *Notre Dame*, look at our lady the guillotine; are silent, becomes serious, and their doubts vanish;—they are converted. This is your *labarum*—*in hoc signo vinces.*”

GULA, GUEULE, or GOLA, in Architecture, a wavy member whose contour resembles the letter S, commonly called an Ogee.

GUNPOWDER, as we have observed in the *Encyclopaedia* under the word GUN, has been known in the east, and particularly in China, from a period of very remote antiquity. No man, however, seems to have suspected that the knowledge of it was conveyed from the east into Europe; but all have agreed to allow the merits

Guillotine
||
Gunpowder.

Plate
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merits of the invention both to friar Bacon and to Bartholomew Schwartz. This generally received opinion has been lately controverted by citizen Langles, who, in a memoir read in the French national institute, contends, that the knowledge of gunpowder was conveyed to us from the Arabs, on the return of the Crusaders to Europe. He assures us that the Arabs made use of it in 690 at the siege of Mecca; and he adds, that they derived it from the Indians, among whom it must have been known in the remotest ages, since their sacred books (the Vedam) forbid the use of it in war.

It is indeed extremely probable, that the composition of gunpowder was known in India at a very early period; for in whatever country nature forms nitre in the greatest plenty, there its deflagrating quality is most likely to be first observed; and a few experiments founded on that observation, will lead to the composition which produces such sudden and violent effects. "Nitre (says Sir George Staunton) is the natural and daily produce of China and India; and there accordingly the knowledge of gunpowder seems to be coeval with that of the most distant historic events. Among the Chinese, it has been applied at all times to useful purposes; such as blasting rocks, and removing great obstructions, and to those of amusement in making a vast variety of fire-works. It was also used as a defence by undermining the probable passage of the enemy, and blowing him up. But its force had not been directed through strong metallic tubes as it was by Europeans soon after they had discovered it. And though, in imitation of Europe, it has been introduced into the armies of the East, other modes of warfare are sometimes still preferred to it."

Of gunpowder manufactured by those who have manufactured it so long, it is desirable to know the composition and the qualities. It was therefore natural for the Hon. George Napier, when superintending the royal laboratory at Woolwich, and making experiments upon so necessary an implement of modern war, to procure some Chinese powder from Canton.

This he did; and analyzing two ounces of it, he found, after repeating the operation six times, that the mean result gave the following proportions*. Nitre 1 oz. 10 dwts. charcoal 6 dwts. sulphur 3 dwts. 14 grs. Here is a deficiency in weight of ten grains, which M. Napier supposes the consequence of some defect in his process; but as M. Baumé, a French chemist, made a variety of experiments to obtain a total separation of the sulphur from the charcoal of gunpowder, and was never able to effect it, one fourteenth part remaining united, three grains must be deducted from the charcoal and added to the sulphur to give the accurate proportion of the ingredients; which by turning to the article GUNPOWDER, *Encycl.* the reader will perceive differs somewhat from the proportion of the same ingredients in the gunpowder of Europe. This Chinese powder was usually large-grained, and not strong, but very durable. It had been made many years when our author got it; yet there was no visible symptom of decay, the grain being hard, well coloured, and though angular, it was even-sized, and in perfect preservation.

When we consider the operations in which gunpowder is employed, it is obvious that it must be an object of importance to ascertain its explosive force; and yet

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there is scarcely a subject concerning which the most approved writers have so much differed. Mr Robins, who has done more towards perfecting the art of gunnery than any other individual, states the explosive force of gunpowder to be 1000 times greater than the mean pressure of the atmosphere; while the celebrated Daniel Barnouilli determines it to be not less than 10,000 times this pressure. Such a difference of opinion led Count Rumford to pursue a course of experiments, of which some were published in the *Transactions of the Royal Society* for the year 1781, and the remainder in the *Transactions of the same Society* for 1797; with the view principally of determining the initial expansive force of gunpowder. By one of these experiments, it appeared, that calculating even on Mr Robins's own principles, the force of gunpowder, instead of being 1000 times, must at least be 1208 times greater than the mean pressure of the atmosphere. From this experiment, the Count thought himself warranted in concluding that the principles assumed by Mr Robins were erroneous, and that his mode of ascertaining the force of gunpowder could never satisfactorily determine it. Despairing of success in that way, he resolved to make an attempt for ascertaining this force by actual measurement; and after many unsuccessful experiments, he was at length led to conclude, that this force was at least 50,000 times greater than the mean pressure of the atmosphere.

Mr Robins apprehends that the force of fired gunpowder consists in the action of a permanently elastic fluid, similar in many respects to common atmospheric air; and this opinion has been very generally received: but Count Rumford thinks, that though the permanently elastic fluids, generated in the combustion of gunpowder, assist in producing the effects which result from its explosion, its enormous force, allowing it to be 50,000 times greater than the mean pressure of the atmosphere, cannot be explained, without supposing that it arises principally from the elasticity of the aqueous vapour generated from the powder in its combustion.

"The brilliant discoveries of modern chemists (says he) have taught us, that both the constituent parts of which water is composed, and even water itself, exist in the materials which are combined to make gunpowder; and there is much reason to believe that water is actually formed, as well as disengaged, in its combustion. M. Lavoisier, I know, imagined that the force of fired gunpowder depends in a great measure upon the expansive force of uncombined caloric, supposed to be let loose in great abundance during the combustion or deflagration of the powder: but it is not only dangerous to admit the action of an agent whose existence is not yet clearly demonstrated; but it appears to me that this supposition is quite unnecessary, the elastic force of the heated aqueous vapour, whose existence can hardly be doubted, being quite sufficient to account for all the phenomena. It is well known that the elasticity of aqueous vapour is incomparably more augmented by any given augmentation of temperature than that of any permanently elastic fluid whatever; and those who are acquainted with the amazing force of steam, when heated only to a few degrees above the boiling point, can easily perceive that its elasticity must be almost infinite when greatly condensed and heated to the

* *Transactions of the Royal Irish Academy.*

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temperature of red-hot iron; and this heat it must certainly acquire in the explosion of gunpowder. But if the force of fired gunpowder arises *principally* from the elastic force of heated aqueous vapour, a cannon is nothing more than a *steam engine* upon a peculiar construction; and upon determining the ratio of the elasticity of this vapour to its density, and to its temperature, a law will be found to obtain very different from that assumed by Mr Robins in his *Treatise on Gunnery*."

In order to measure the elastic force of fired gunpowder, Count Rumford adopted a new plan; and, instead of causing the generated elastic fluid to act on a moveable body through a determined space, which he had found to be ineffectual to his purpose, he contrived an apparatus in which this fluid should be made to act, "by a determined surface, against a weight, which, by being increased at pleasure, should at last be such as would just be able to confine it, and which in that case would just counterbalance and consequently *measure* the elastic force."

Having succeeded in setting fire to the powder, without any communication with the external air, "by causing the heat employed for that purpose to pass through the solid substance of the barrel, it only remained to apply such a weight to an opening made in the barrel, as the whole force of the generated elastic fluid should not be able to lift, or displace." Many precautions were necessary. A solid block of very hard stone, four feet four inches square, was placed upon a bed of solid masonry, which descended six feet below the surface of the earth. Upon this block of stone, which served as a base to the whole machinery, was placed the small barrel, in which the explosions were made, with its opening directly upwards. This opening was closed by a solid hemisphere of hardened steel, on which the weight to be overcome by the explosion was laid. Having charged the barrel with 10 grains of powder, its whole contents being about 28 grains, and a 24 pounder, weighing 8081 lbs. avoirdupois, being placed on its cascade so as by its weight to confine the generated elastic fluid, a heated iron ball was applied to the end of the vent tube (a small solid projection from the centre of the bottom of the barrel). In a few moments the powder took fire, though the explosion made a very feeble report; and when the weight was raised, the confined elastic vapour rushed out of the barrel. The slight effect produced by this explosion induced some of the attendants on this occasion to undervalue the importance of this experiment, and to form a very inadequate idea of the real force of the elastic fluid that had been thus almost insensibly discharged. In a second experiment, the barrel was filled with powder, and the same weight laid on as before. The barrel was made of the best hammered iron, and uncommonly strong. The charge of powder amounted to little more than $\frac{1}{10}$ th of a cubic inch, which is not so much as would be required to load a small pocket-pistol, and not *one-tenth* part of the quantity frequently used for the charge of a common musket. Yet this inconsiderable quantity of powder, when set on fire, exploded with a force that burst the barrel, and with a loud report that alarmed the whole neighbourhood.

The author proceeds to make an estimate, from the known strength of iron, and the area of the fracture of

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the barrel in the preceding experiment, of the real force employed by the elastic vapour to burst it; and he computes that it must have been equal to the pressure of a weight of 412529 lbs.; which, by another computation, he found to be 55004 times greater than the mean pressure of the atmosphere. By another process, he investigates the strength of the iron of which the barrel was made; and he thence finds that the force required to burst it was equal to the pressure of a weight of 410624 $\frac{1}{2}$ lbs. This weight, reduced into atmospheres, gives 54750 atmospheres for the measure of the force exerted by the elastic fluid in the present instance. This force must be considerably less than the initial force of the elastic fluid generated in the combustion of gunpowder, before it has begun to expand; "for it is more than probable (says Count Rumford) that the barrel was in fact burst before the generated elastic fluid had exerted all its force, or that this fluid would have been able to have burst a barrel still stronger than that used in the experiment."

After having shewn the extreme force of fired gunpowder, the Count adverts to an objection which may be made against his deductions. How does it happen that fire-arms and artillery of all kinds, which certainly are not calculated to withstand so enormous a force, are not always burst when they are used? Instead of answering this question, by asking how it happened that the extremely strong barrel used in his experiment could be burst by the force of gunpowder, if this force be not in fact much greater than it has ever been supposed to be, he proceeds to shew that the combustion of gunpowder, instead of being instantaneous, as Mr Robins's theory supposes, is much less rapid than has hitherto been apprehended; an observation which, if established, is certainly sufficient to answer the objection.

He remarks, that it is a well-known fact that, on the discharge of fire-arms of all kinds, there is always a considerable quantity of unconsumed grains of gunpowder blown out of them; and what is very remarkable, as it leads directly to a discovery of the cause of this effect, these unconsumed grains are not merely blown out of the muzzles of fire-arms, but come out also by their vents or touch-holes, where the fire enters to inflame the charge, as many persons who have had the misfortune to stand with their faces near the touch-hole of a musket, when it has been discharged, have found to their cost.

It appears extremely improbable to our author, if not absolutely impossible, that a grain of gunpowder actually in the chamber of the piece, and completely surrounded by flame, should, by the action of that very flame, be blown out of it without being at the same time set on fire. And, if this be true, he considers it as a most decisive proof, not only that the combustion of gunpowder is less rapid than it has generally been thought to be, but that a grain of gunpowder actually on fire, and burning with the utmost violence over the whole of its surface, may be projected with such a velocity into a cold atmosphere, as to extinguish the fire, and suffer the remains of the grain to fall to the ground unchanged, and as inflammable as before.

This extraordinary fact was ascertained beyond all possibility of doubt by the Count's experiments. Having procured from a powdermill in the neighbourhood of the city of Munich a quantity of gunpowder, all of the same mass, but formed into grains of very different sizes,

Gunpow- der. sizes, some as small as the grains of the finest Battel powder, he placed a number of vertical screens of very thin paper, one behind another, at the distance of 12 inches from each other; and loading a common musket repeatedly with this powder, sometimes without and sometimes with a wad, he fired it against the foremost screen, and observed the quantity and effects of the unconsumed grains of powder which impinged against it. The screens were so contrived, by means of double frames united by hinges, that the paper could be changed with very little trouble, and it was actually changed after every experiment.

The distance from the muzzle of the gun to the first screen was not always the same; in some of the experiments it was only 8 feet, in others it was 10, and in some 12 feet.

The charge of powder was varied in a great number of different ways; but the most interesting experiments were made with one single large grain of powder, propelled by smaller and larger charges of very fine grained powder.

These large grains never failed to reach the screen; and though they sometimes appeared to have been broken into several pieces by the force of the explosion, yet they frequently reached the screen entire; and sometimes passed through all the screens (five in number) without being broken.

When they were propelled by large charges, and consequently with great velocity, they were seldom on fire when they arrived at the first screen; which was evident, not only from their not setting fire to the paper (which they sometimes did), but also from their being found sticking in a soft board, against which they struck, after having passed through all the five screens; or leaving visible marks of their having been impinged against it, and being broken to pieces and dispersed by the blow. These pieces were often found lying on the ground; and from their forms and dimensions, as well as from other appearances, it was often quite evident that the little globe of powder had been on fire, and that its diameter had been diminished by the combustion before the fire was put out, on the globe being projected into the cold atmosphere.

That these globes or large grains of powder were always set on fire by the combustion of the charge, can hardly be doubted. This certainly happened in many of the experiments; for they arrived at the screens on fire, and set fire to the paper; and in the experiments in which they were projected with small velocities, they were often seen to pass through the air on fire; and when this was the case, no vestige was to be found. They sometimes passed on fire through several of the foremost screens without setting them on fire, and set fire to one or more of the hindmost, and then went on and impinged against the board which was placed at the distance of twelve inches behind the last screen.

The Count then proceeds to mention another experiment, in which the progressive combustion of gunpowder was shewn in a manner still more striking, and not less conclusive.

A small piece of red hot iron being dropped down into the chamber of a common horse pistol, and the pistol being elevated to an angle of about 45 degrees, upon dropping down into its barrel one of the small

globes of powder (of the size of a pea), it took fire, and was projected into the atmosphere by the elastic fluid generated in its own combustion, leaving a very beautiful train of light behind it, and disappearing all at once like a falling star. This amusing experiment was repeated very often, and with globes of different sizes. When very small ones were used singly, they were commonly consumed entirely before they came out of the barrel of the pistol; but when several of them were used together, some, if not all of them, were commonly projected into the atmosphere on fire.

As the slowness of the combustion of gunpowder is undoubtedly the cause which has prevented its enormous and almost incredible force from being discovered, our author deduces, as an evident consequence, that the readiest way to increase its effects, is to contrive matters so as to accelerate its inflammation and combustion. This may be done in various ways; but, in his opinion, the most simple and most effectual manner of doing it would be to set fire to the charge of powder, by shooting (through a small opening) the flame of a smaller charge into the midst of it.

He contrived an instrument on this principle for firing cannon three or four years ago; and it was found, on repeated trials, to be useful, convenient in practice, and not liable to accidents. It likewise supercedes the necessity of using priming, of vent tubes, port-fires, and matches; and on that account he imagined it might be of use in the British navy, but it does not appear to have been received into practice.

Another infallible method of increasing very considerably the effect of gunpowder in fire-arms of all sorts and dimensions, would be to cause the bullet to fit the bore exactly, or without windage, in that part of the bore at least where the bullet rests on the charge; for when the bullet does not completely close the opening of the chamber, not only much of the elastic fluid, generated in the first moment of the combustion of the charge, escapes by the side of the bullet; but what is of still greater importance, a considerable part of the unconsumed powder is blown out of the chamber along with it in a state of actual combustion, and, getting before the bullet, continues to burn on as it passes through the whole length of the bore; by which the motion of the bullet is much impeded.

The loss of force which arises from this cause, is in some cases almost incredible; and it is by no means difficult to contrive matters so as to render it very apparent, and also to prevent it.

If a common horse-pistol be fired with a loose ball, and so small a charge of powder that the ball shall not be able to penetrate a deal board so deep as to stick in it when fired against it from the distance of six feet; the same ball, discharged from the same pistol with the same charge of powder, may be made to pass quite through one deal board, and bury itself in a second placed behind it, merely by preventing the loss of force which arises from what is called windage, as he found more than once by actual experiment.

The Count has in his possession a musket, from which, with a common charge of powder, he fires two bullets at once with the same velocity that a single bullet is discharged from a musket on the common construction with the same quantity of powder. And, what renders the experiment still more striking, the diameters

Gunpow-
der.Gunter,
Gut-tie.

diameter of the bore of his musket is exactly the same as that of a common musket, except only in that part of it where it joins the chamber, in which part it is just so much contracted, that the bullet, which is next to the powder, may stick fast in it. He adds, that though the bullets are of the common size, and are consequently considerably less in diameter than the bore, means are used which effectually prevent the loss of force by windage; and to this last circumstance he concludes, it is doubtless owing, in a great measure, that the charge appears to exert so great a force in propelling the bullets.

That the conical form of the lower part of the bore where it unites with the chamber has a considerable share in producing this extraordinary effect, is, however, very certain, as he has found by experiments made with a view merely to ascertain that fact.

At the close of the Count's last memoir, we have a computation, designed to shew that the force of the elastic fluid generated in the combustion of gunpowder, enormous as it is, may be satisfactorily explained on the supposition that it depends *solely* on the elasticity of watery vapour, or steam. From experiments made in France in the year 1790, it appears that the elasticity of steam is doubled by every addition of temperature equal to 30° of Fahrenheit's thermometer. As the heat generated in the combustion of gunpowder cannot be less than that of red-hot iron, it may be supposed equal to 1000° of Fahrenheit's scale:—but the elastic force of steam is just equal to the mean pressure of the atmosphere, when its temperature is equal to that of boiling water, or to 212° of Fahrenheit's thermometer; consequently $212° + 30° = 240°$ will represent the temperature, when its elasticity will be equal to the pressure of two atmospheres; and, pursuing the calculation, at 602°, or 2° above the heat of boiling linseed oil, its elasticity will be equal to the pressure of 8192 atmospheres, or above *eight times* greater than the utmost force of the fluid generated in the combustion of gunpowder, according to Mr Robins's computation: but the heat in this case is much greater than that of 602° of Fahrenheit; and therefore the elasticity of the steam generated from the water contained in the powder must be much greater than the pressure of 8192 atmospheres. At 722°, the elasticity will be equal to the pressure of 131,072 atmospheres; and this temperature is less than the heat of iron, which is visibly red-hot in day-light, by 355°:—but the flame of gunpowder has been found to melt brass, which requires a heat equal to that of 3807° of Fahrenheit; 2730° above the heat of red-hot iron, or 3805° higher than the temperature which gives to steam an elasticity equal to the pressure of 131,072 atmospheres. That there is in gunpowder water sufficient for supplying the necessary quantity of steam, the author has very satisfactorily evinced; but we must not pursue his curious investigations any farther. Those who want a fuller account of them, will find it either in the original memoirs themselves, or in a very accurate abridgment of these memoirs in the first volume of Nicholson's *Journal of Natural Philosophy*, &c.

We cannot conclude this article without mentioning a new kind of gunpowder, invented some years ago in France, in which the marine acid is substituted, in equal quantity, for nitre. Dr Hutton tried some of

this new powder which was made at Woolwich, and found it of about double the strength of the ordinary sort; but it is not likely to come into common and general use, for the preparation of the acid is difficult and expensive (See *CHEMISTRY-Index* in this *Suppl.*), and the powder which is made of it catches fire and explodes from the smallest degree of heat, and without the aid of a spark. It is to this circumstance, however, that its superior strength seems to be in a great measure owing.

GUNTER'S CHAIN. See *GEOMETRY, Encyclopædia*, Part II. chap. 1.

GUT-TIE, a dangerous disease to which oxen and male calves are rendered liable by an improper mode of castration. In some places, and particularly in Herefordshire, the breeders of cattle, when they castrate their calves, open the *scrotum*, take hold of the testicles with their teeth, and tear them out with violence; by which means all the vessels thereto belonging are ruptured. The *vasa deferentia*, entering by the holes of the transverse and oblique muscles into the abdomen, pass over the ureters in acute angles; at which turning, by their great length and elastic force, the peritoneum is ruptured; the *vasa deferentia* are severed from the testicles, and, springing back, form a kind of bow from the urethra, where they are united, over the ureters, to the transverse and oblique muscles, and there again unite, where they first entered the abdomen; the part of the gut that is tied is the jejunum, at its turning from the left side to the right, and again from the right to the left, forming right angles under the kidney, and attached to the duplicature of the peritoneum, to which it was united, where the rupture happened. There the bow of the gut hangs over the bow of the *vasa deferentia*, which, by a sudden motion, or turn of the beast, form a hitch or tie of the string round the bow of the gut (filled with air), similar to what a carter makes on his cart line. This causes a stoppage in the bowels, and brings on a mortification, which, in two days, or four at most, proves fatal: And to this accident is the beast, when castrated as above, liable from the day that he was castrated till the time of his being slaughtered.

The symptoms of the gut-tie are the same as those of an incurable colic, *volvulus*, or mortification of the bowels. The beast affected with this complaint will kick at its belly, lie down, and groan; it has also a total stoppage in its bowels (except blood and mucus, which it will void in large quantities), and a violent fever, &c. To distinguish with certainty the gut-tie from the colic, &c. the hand and arm of the operator must be oiled, and introduced into the anus, through the rectum, beyond the os pubis, turning the hand down to the transverse and oblique muscles, where the vessels of the testicles enter the abdomen. There the string will be found united to the muscles, and is easily traced to the stricture by the hand, without pain to the beast.

From the general view of the agriculture of the county of Hereford, drawn up by Mr Clark of Builth, Breconshire, we learn that Mr Harris farmer at Wickton, near Leominster, had been uncommonly successful in the cure of the gut-tie. That gentleman informs us, that he had cut cattle for this disease from the age of three months to that of nine years; and as it is a matter of great importance, we shall state his method of operating in his own words.

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Gut-tie.

Gut-tie,
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“ The only method of cure (says he) that can be safely ventured upon is, to make a perpendicular incision, four inches under the third vertebra of the loins, on the left side, over the paunch or stomach, and introduce the arm to find the part affected; if possible, keep the beast standing by the help of proper assistants. The knife I make use of to sever the string is in the form of a large fish-hook, with an edge on the concave side; it is fixed to a ring, which fits the middle finger, which finger crooks round the back of the knife, the end of the thumb being placed on its edge. The instrument, by being thus held in the hand, is secured from wounding the surrounding intestines; with it I divide the string or strings, and bring out one or both, as circumstances require. Here it is to be observed, that great care must be taken by the operator not to wound or divide the ureters, which would be certain death. I then sew up the divided lips of the peritoneum very close, with a surgeon's needle threaded with strong thread, eight or ten double, sufficiently waxed; I also sew up the skin, leaving a vacancy at the top and bottom of the wound sufficiently wide to introduce a tent of surgeon's tow, spread with common digestive and traumatic balsam; covering the incision with a plaster made of the whites of eggs and wheat flour. The wound, thus treated, and dressed every day, will be

well in a fortnight. The medicine I give to remove the stoppage in the three stomachs occasioned by the tie, and to carry off the fever, is four ounces of Glauber's salt, two ounces of cream of tartar, and one ounce of fenna, infused in two pounds of boiling water, adding half a pound of olive-oil, and working it off with plenty of gruel, mixed with a large quantity of infusion of mallows and elder-bark. I administer the gruel and infusion for at least two or three days; by which time the beast will be well, will eat his provender, and chew the cud, and will forever be relieved, and remain safe from this fatal disorder.

“ The following simple and easy method of castration will effectually prevent the gut-tie. Open the scrotum, loosen out the testicles, and tie the several vessels with a waxed thread or silk; or fear them with a hot iron, to prevent their bleeding, as in the common way of cutting colts. This method can never displace the vessels of the testicles, bladder, kidneys, or intestines; all of which remain covered or attached to the peritoneum, or lining of the abdomen of the beast, which renders it impossible that there should ever be a stricture or tie on the gut.”

GUZ, an Indian measure, varying in different places, but which may be reckoned about an English yard, The guz of Akbar was 41 fingers.

H.

Hances
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Harriot.

Harriot.

HANCES, HANCHES, HAUNCHES, or Hances, in architecture, are certain small intermediate parts of arches between the key or crown and the spring at the bottom, being perhaps about one-third of the arch, and situated nearer the bottom than the top or crown; and are otherwise called the *spandrels*. See ARCH in this Supplement.

HANSPIKE, or HANDSPEC, a lever or piece of strong wood, for raising by the hand great weights, &c. It is five or six feet long, cut thin and crooked at the lower end, that it may get the easier between things that are to be separated, or under any thing that is to be raised. It is better than a crow of iron, because its length allows a better poise.

HARRIOT (Thomas) was a very eminent mathematician of the 16th and 17th centuries, of whom some account has been given in the *Encyclopædia Britannica*. In that article it has been shewn, that Des Cartes had seen some improvements of Harriot's in algebra, and published them to the world as his own; but this piece of plagiarism has been more completely proved in the *Astronomical Ephemeris* for the year 1788, by Dr Zache, astronomer to the Duke of Saxe-Gotha; who likewise shews that Harriot was an astronomer as well as an algebraist.

“ I here present to the world (says the Doctor) a short account of some valuable and curious manuscripts, which I found in the year 1784 at the seat of the earl of Egremont, at Petworth in Suffex.

“ A predecessor of the family of lord Egremont, viz. that noble earl of Northumberland, named Henry Percy, was not only a generous favourer of all good learning, but also a patron and Mæcenas of the learned men of his age. Thomas Harriot, the author of the said manuscripts, Robert Hues (well known by his *Treatise upon the Globes*), and Walter Warner, all three eminent mathematicians, who were known to the earl, received from him yearly pensions; so that when the earl was committed prisoner to the Tower of London in the year 1606, our author, with Hues and Warner, were his constant companions; and were usually called the earl of Northumberland's three Magi.

“ Thomas Harriot is a known and celebrated mathematician among the learned of all nations, by his excellent work, *Artis Analytica Praxis, ad equationes algebraicas nova expeditata & generali methodo, resolvendas, Tractatus posthumus*; London 1631: dedicated to Henry earl of Northumberland; published after his death by Walter Warner. It is remarkable, that the fame and the honour of this truly great man were constantly attacked by the French mathematicians, who could not endure that Harriot should in any way diminish the fame of their Vieta and Des Cartes, especially the latter, who was openly accused of plagiarism from our author.

“ Des Cartes published his *Geometry* six years after Harriot's work appeared, viz. in the year 1637. Sir Charles Cavendish, then ambassador at the French court

Harriot. at Paris, observed to the famous geometrician Roverval, that these improvements in analysis had been already made these six years in England, and shewed him afterwards Harriot's *Artis Analyticæ Praxis*; which, as Roverval was looking over, at every page he cried out, *Où! où! il l'a vu! Yes! yes! he has seen it!* Des Cartes had also been in England before Harriot's death, and had heard of his new improvements and inventions in analysis.

“ Now all this relates to Harriot the celebrated analyst; but it has not hitherto been known that Harriot was an eminent astronomer, both theoretical and practical, which first appears by these manuscripts; among which, the most remarkable are 199 observations of the sun's spots, with their drawings, calculations, and determination of the sun's rotation about his axis. There is the greatest probability that Harriot was the first discoverer of these spots, even before either Galileo or Scheiner. The earliest intelligence we have of the first discovered solar spots is of one Joh. Fabricius Phrylius, who in the year 1611 published at Wittenberg a small treatise, intitled, *De Maculis in Sole observatis & apparente eorum cum Sole conversione narratio*. Galileo, who is commonly accounted the first discoverer of the solar spots, published his book, *Istoria e Dimostrazioni intorno alle Macchie Solare e loro accidente*, at Rome in the year 1613. His first observation in this work is dated June 2d 1612. Angelo de Filiis, the editor of Galileo's work, who wrote the dedication and preface to it, mentions, page 3. that Galileo had not only discovered these spots in the month of April in the year 1611, at Rome, in the Quirinal Garden, but had shewn them several months before (*molti mesi innanzi*) to his friends in Florence; and that the observations of the disguised Apelles (the Jesuit Scheiner, a pretender to this first discovery) were not later than the month of October in the same year; by which the epoch of this discovery was fixed to the beginning of the year 1611. But a passage in the first letter of Galileo's works, pa. 11. gives a more precise term to this discovery. Galileo there says in plain terms, that he had observed the spots in the sun 18 months before. The date of this letter is May 24. 1612; which brings the true epoch of this discovery to the month of November 1610. However, Galileo's first produced observations are only from June 2. 1612, and those of father Scheiner of the month of October in the same year. But now it appears from Harriot's manuscripts, that his first observations of these spots are of Dec. 8. 1610. It is not likely that Harriot could have this notice from Galileo, for I do not find this mathematician's name ever quoted in Harriot's papers: But I find him quoting book i. chap. 2. of Joseph a Costa's *Natural and Moral History of the West Indies*; in which he relates, that in Peru there are spots to be seen in the sun which are not seen in Europe: and hence it is probable, that Harriot took the hint of looking for such spots. Besides, it is not unlikely, that living with so munificent a patron, Harriot got from Holland the new invented telescopes much sooner than they could reach Galileo, who at that time lived at Venice. Harriot's very careful and exact observations of these spots, shew also that he was in possession of the best and most improved telescopes of that time; for it appears he had some with magnifying powers of 10, 20, and 30 times. At least there are no earlier observations of the solar

spots extant than his; they run from December 8. 1610, till January 18. 1613. I compared the corresponding ones with these observed by Galileo, between which I found an exact agreement. Had Harriot had any notion about Galileo's discoveries, he certainly would have also known something about the phases of Venus and Mercury, and especially about the singular shape of Saturn, first discovered by Galileo; but I find not a word in all his papers concerning the particular figure of that planet.

“ I found likewise (continues Dr Zach) among the papers of Harriot a large set of observations on the satellites of Jupiter, with drawings of them, their positions, and calculations of their revolutions and periods. His first observation of those discovered satellites, I find to be of January 16. 1610; and they go till February 26. 1612. Galileo pretends to have discovered them January 7. 1610; so that it is not improbable that Harriot was likewise the first discoverer of these attendants of Jupiter.

“ Among his other observations of the moon, of eclipses, of the planet Mars, of solstices, of refraction, of the declination of the needle, &c. there are remarkable ones of the comet of 1607, and the latter comet (for there were two) of 1618. They were all observed with a cross-staff, by measuring their distances from fixed stars; whence these observations are the more valuable, as comets had before been but grossly observed. Kepler himself observed the comet of 1607 only with the naked eye, pointing out its place by a coarse estimation, without the aid of an instrument; and the elements of their orbits could, in defect of better observations, be only calculated by them. The observations of the comet of the year 1607 are of the more importance, even now for modern astronomy, as this is the same comet that fulfilled Dr Halley's prediction of its return in the year 1759. That prediction was only grounded upon the elements afforded him by these coarse observations; for which reason he only assigned the term of its return to the space of a year. The very intricate calculations of the perturbations of this comet, afterwards made by M. Clairaut, reduced the limits to a month's space. But a greater light may now be thrown upon this matter by the more accurate observations on this comet by Mr Harriot. In the month of October 1785, when I conversed upon the subject of Harriot's papers, and especially on this comet, with the celebrated mathematician M. de la Grange, director of the Royal Academy of Sciences at Berlin, he then suggested to me an idea, which, if brought into execution, will clear up an important point in astronomy. It is well known to astronomers how difficult a matter it is to determine the mass, or quantity of matter, in the planet Saturn; and how little satisfactory the notions of it are that have hitherto been formed. The whole theory of the perturbations of comets depending upon this uncertain datum, several attempts and trials have been made towards a more exact determination of it by the most eminent geometricians of this age, and particularly by la Grange himself; but never having been satisfied with the few and uncertain data heretofore obtained for the resolution of this problem, he thought that Harriot's observations on the comet of 1607, and the modern ones of the same comet in 1759, would suggest a way of resolving the problem *à posteriori*; that of determining

Hasselquist by them the elements of its ellipsis. The retardation of the comet, compared to its period, may clearly be laid to the account of the attraction and perturbation it has suffered in the region of Jupiter and Saturn; and as the part of it belonging to Jupiter is very well known, the remainder must be the share which is due to Saturn; whence the mass of the latter may be inferred. In consequence of this consideration, I have already begun to reduce most of Harriot's observations of this comet, in order to calculate by them the true elements of its orbit on an elliptical hypothesis, to complete M. de la Grange's idea upon this matter.

"I forbear to mention here any more of Harriot's analytical papers, which I found in a very great number. They contain several elegant solutions of quadratic, cubic, and biquadratic equations; with some other solutions and *locæ geometricæ*, that shew his eminent qualifications, and will serve to vindicate them against the attacks of several French writers, who refuse him the justice due to his skill and accomplishments, merely to save Des Cartes's honour, who yet, by some impartial men of his own nation, was accused of public plagiarism."

HASSELQUIST (Frederick) was born in the province of East Gothland in 1722, and studied medicine and botany in the university of Upsal. Linnæus had in his lectures represented the extraordinary merits and great celebrity which a young student might obtain by travelling through Palestine, and by inquiring into and describing the natural history of that country, which was till then unknown, and had become of the greatest importance to interpret the bible, and to understand eastern philology. Hasselquist was fired with ambition to accomplish an object so important in itself, and so warmly recommended by his beloved master. There being no fund arising from the liberality of the crown, private collections were made, which poured in very copiously, especially from the native country of the young traveller. All the faculties of the university of Upsal also granted him a stipend.

Thus protected, he commenced his journey in the summer of 1749. By the interference of Lagerstroem, he had a free passage to Smyrna in one of the Swedish East Indiamen. He arrived there at the conclusion of the year, and was received in the most friendly manner by Mr A. Rydel, the Swedish consul. In the beginning of 1750 he set out for Egypt, and remained nine months at Cairo the capital. Hence he sent to Linnæus, and to the learned societies of his country, some specimens of his researches. They were published in the public papers, and met with the greatest approbation; and upon the proposition of Dean Bæck and Dr Wargentia, secretary of the Royal Academy of Sciences, a collection of upwards of 10,000 dollars in copper money was made for the continuance of the travels of young Hasselquist. Counsellors Lagerstroem and Nordencrantz were the most active in raising subscriptions at Stockholm and Gothenburgh. In the spring of 1751, he repaired to his destination, and passed through Jaffa to Jerusalem, Jericho, &c. He returned afterwards through Rhodus and Scio to Smyrna. Thus he fulfilled all the expectations of his country, but he was not to reap the reward of his toils. The burning heat

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of the sandy deserts of Arabia had affected his lungs; he reached Smyrna in a state of illness, in which he languished for some time, and died February 9. 1752, in the 30th year of his age.

Hat.

The fruits of his travels were, however, preserved through the liberality of a great princess. He had been obliged to contract debts. The Turks, therefore, seized upon all his collections, and threatened to expose them to public sale. The Swedish consul prevented it. He sent, with the intelligence of the unhappy exit of his countryman, an account of the distresses under which he died;—and at the representation of Dean Bæck, Queen Louisa Ulrica granted the sum of 14,000 dollars in copper specie to redeem all his collections. They arrived afterwards in good preservation at Stockholm; consisting of a great quantity of antiques, Arabian manuscripts, shells, birds, serpents, insects, &c. and were kept in the cabinets at Ulrichsdale and Drottningholm. The specimens of the natural curiosities of these museums being double or treble in number, Linnæus obtained some of them, and published the voyage of his ill-fated friend, and honoured his memory with a plant which he called from his name *Hasselquistia*. HASSELQUISTA, *Encycl.*

HAT-MAKING is a mechanical process, which is detailed in the *Encyclopædia* from the best information that could then be obtained. We have lately learned, however, that our detail is sometimes defective, and sometimes erroneous; and it is our duty to supply those defects, and to correct those errors. But, strangers as we are to the business of hat-making, we should not perhaps have suspected, that we had been misled by the persons whom we consulted, had we not been informed by a very intelligent writer in Nicholson's Philosophical Journal, that the account of the manufacturing of hats, which is given in the *Encyclopædia*, is far from the truth. This information induced us to look through the Journal itself for a more accurate account of the process; well convinced, that the liberal-minded author of that work would not have pointed out our mistakes without making us welcome to avail ourselves of his aid to correct them. Our readers will therefore be indebted only to Mr Nicholson and his correspondent for whatever instruction they may derive from this article; and as we wish not to deck ourselves in borrowed plumes, we shall communicate that instruction in the words of its author.

Having visited the manufactory of Messrs Collinsons, hatters in Gravel-lane, Southwark, Mr Nicholson gives the following account of their procedure:

"The materials for making hats are rabbits fur cut off from the skin, after the hairs have been plucked out, together with wool and beaver. The two former are mixed in various proportions, and of different qualities, according to the value of the article intended to be made; and the latter our author believes to be universally used for facing the finer articles, and never for the body or main stuff. Experience has shewn, that these materials cannot be evenly, and well felted together, unless all the fibres be first separated, or put into the same state with regard to each other. This is the object of the first process, called *bowing*. The material, without any previous preparation (A), is laid upon a platform of wood,

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or

(A) Some writers mention a partial wetting of the fur while on the skin, by lightly smearing it with a solution of nitrate of mercury to give it a curl. Messrs Collinsons do not use it, nor any other preparation.

Hat.

Hat.

or of wire, somewhat more than four feet square, called a *hurdle*, which is fixed against the wall of the workshop, and is enlightened by a small window, and separated by two side partitions from other hurdles which occupy the rest of the space along the wall. The hurdle, if of wood, is made of deal planks, not quite three inches wide, disposed parallel to the wall, and at the distance of one-fortieth or one-fiftieth of an inch from each other, for the purpose of suffering the dust, and other impurities of the stuff, to pass through; a purpose still more effectually answered by the hurdle of wire.

“The workman is provided with a bow, a bow-pin, a basket, and several cloths. The bow is a pole of yellow deal wood, between seven and eight feet long, to which are fixed two bridges, somewhat like that which receives the hair in the bow of the violin (B). Over these is stretched a catgut, about one-twelfth part of an inch in thickness. The bow pin is a stick with a knob, and is used for plucking the bow-string. The basket is a square piece of osier work, consisting of open straight bars with no crossing or interweaving. Its length across the bars may be about two feet, and its breadth eighteen inches. The sides into which the bars are fixed are slightly bended into a circular curve, so that the basket may be set upright on one of these edges near the right hand end of the hurdle, where it usually stands. The cloths are linen. Besides these implements, the workman is also provided with brown paper.

“The *bowing* commences by shovelling the material towards the right hand partition with the basket; upon which, the workman holding the bow horizontally in his left hand, and the bow-pin in his right, lightly places the bow-string, and gives it a pluck with the pin. The string, in its return, strikes part of the fur, and causes it to rise, and fly partly across the hurdle in a light open form. By repeated strokes, the whole is thus subjected to the bow; and this beating is repeated till all the original clots or masses of the filaments are perfectly opened and obliterated. The quantity thus treated at once is called a *batt*, and never exceeds half the quantity required to make one hat.

“When the batt is sufficiently bowed, it is ready for *hardening*; which term denotes the first commencement of felting. The prepared material being evenly disposed on the hurdle, is first pressed down by the convex side of the basket, then covered with a cloth, and pressed successively in its various parts by the hands of the workman. The pressure is gentle, and the hands are very slightly moved back and forwards at the same time through a space of perhaps a quarter of an inch, to favour the hardening or entangling of the fibres (See *FELTING* in this *Suppl.*) In a very short time, indeed, the stuff acquires sufficient firmness to bear careful handling. The cloth is then taken off, and a sheet of paper, with its corners doubled in, so as to give it a triangular outline, is laid upon the batt, which last is folded over the paper as it lies, and its edges, meeting one over the other, form a conical cap. The joining is soon made good by pressure with the hands on the cloth. Another batt, ready hardened, is in the next place laid on the hurdle, and the cap here mentioned placed upon it, with the joining downwards. This last batt being also folded up, will consequently have its place of junction diametrically opposite to that of the inner felt, which it must therefore greatly tend to strengthen. The principal part of the hat is thus put together, and now requires to be worked with the hands a considerable time upon the hurdle, the cloth being also occasionally sprinkled with clear water. During the whole of this operation, which is called *basoning* (C), the article becomes firmer and firmer, and contracts in its dimensions. It may easily be understood, that the chief use of the paper is to prevent the sides from felting together.

“The *basoning* is followed by a still more effectual continuation of the felting, called *working* (D). This is done in another shop, at an apparatus called a *battery*, consisting of a *kettle* (containing water slightly acidulated with sulphuric acid, to which, for beaver hats, a quantity of the grounds of beer is added, or else plain water for rinsing out), and eight *planks* of wood joined together in the form of a frustum of a pyramid, and meeting in the kettle at the middle. The outer or upper edge of each plank is about two feet broad, and rises

(B) Mr Nicholson's correspondent, who is himself a hatter, says that the bow is best made of ash; that it is composed of the *slang* or handle; that the bridge at the smaller end, or that which is nearest the window in the act of bowing, is called the *cock*; and that the other bridge, which is nearer to the workman's hand, is called the *breech*.

(C) Mr Nicholson's correspondent says, that after bowing, and previous to the basoning, a *hardening skin*, that is, a large piece of skin, about four feet long and three feet broad, of leather alumed or half tanned, is pressed upon the bat, to bring it by an easier gradation to a compact appearance; after which it is basoned, being still kept upon the hurdle. This operation, the basoning, derives its name from the process or *mode of working*, being the same as that practised upon a wool hat after bowing; the last being done upon a piece of cast metal, four feet across, of a circular shape, called a *bason*: the joining of each batt is made good here by shuffling the hand, that is, by rubbing the edge of each batt folded over the other to excite the progressive motion of each of the filaments in felting, and to join the two together. Many journeymen, to hurry this work, use a quantity of vitriol (sulphuric acid), and then, to make the nap rise and flow, they kill the vitriol, and open the body again by throwing in a handful or two of oatmeal; by this means they get a great many made, though, at the same time, they leave them quite grainy from the want of labour. This, in handling the dry grey hat when made, may be in part discovered; but in part only.

(D) The intelligent writer who has been so often quoted, says, that before this operation is begun, the bat is dipped into the boiling kettle, and allowed to lie upon the plank until cold again; this is called *soaking*, that is, being perfectly saturated with the hot liquor: if they are put in too hastily in this state, for they are then only bowed and basoned, they would burst from the edges, each batt not being sufficiently felted into the other.

Hat. rises a little more than two feet and a half above the ground; and the slope towards the kettle is considerably rapid, so that the whole battery is little more than six feet in diameter. The quantity of sulphuric acid added to the liquor is not sufficient to give a four taste, but only renders it rough to the tongue. In this liquor, heated rather higher than unpractised hands could bear, the article is dipped from time to time, and then worked on the planks with a roller, and also by folding or rolling it up, and opening it again; in all which, a certain degree of care is at first necessary, to prevent the sides from felting together; of which, in the more advanced stages of the operation, there is no danger. The imperfections of the work now present themselves to the eye of the workman, who picks out knots and other hard substances with a bodkin, and adds more felt upon all such parts as require strengthening. This added felt is patted down with a wet brush, and soon incorporates with the rest. The beaver is laid on towards the conclusion of this kind of working. Mr Nicholson could not distinctly learn why the beer grounds were used with beaver-hats. Some workmen said, that by rendering the liquor more tenacious, the hat was enabled to hold a greater quantity of it for a longer time; but others said, that the mere acid and water would not adhere to the beaver facing, but would roll off immediately when the article was laid on the plank. It is probable, as he observes, that the manufacturers who now follow the established practice, may not have tried what are the inconveniences this addition is calculated to remove."

Our author's correspondent, however, assigns several reasons for the addition of those dregs, which, he says, ought to be thick, and the sourest that can be got. 1. Vitriol (sulphuric acid) would harden the hat too much, which is kept mellow by the dregs. 2. The dregs are said by the workmen to hold or fill the body, whilst a little vitriol cleanses it of the dirt, &c. that may be on the rabbit or other wools. 3. Another advantage attending the use of dregs, whether of beer, porter, or wine, is, that as the boiling of the dyeing does not draw out much of the mucilage from each hat when it comes to be stiffened, the dregs form a body within the hat, sufficiently strong or retentive to keep the glue from coming through amongst the nap. 4. Vitriol (sulphuric acid) alone purges or weakens the goods too much; consequently half of the quantity does better with the addition of dregs, as it allows the body to be made closer by more work.

Of these four reasons for the use of dregs, the last alone appears to us perspicuous or at all satisfactory. But be this as it may, acid of some kind gives a roughness to the surface of the hair, which facilitates the mechanical action of felting; and Mr Collinson informed Mr Nicholson, that in a process, called *carotting*, they make use of nitrous acid. In this operation, the material is put into a mixture of the nitrous and sulphuric acids in water, and kept in the digesting heat of a stove all night; by which means the hair acquires a ruddy or yellow colour, and loses part of its strength.

"It must be remembered, that our hat still possesses the form of a cone, and that the whole of the several actions it has undergone have only converted it into a soft flexible felt, capable of being extended, though with some difficulty, in every direction. The next thing to

Hat. be done is to give it the form required by the wearer. For this purpose, the workman turns up the edge or rim to the depth of about an inch and a half, and then returns the point back again through the centre or axis of the cap, so far as not to take out this fold, but to produce another inner fold of the same depth. The point being returned back again in the same manner; produces a third fold; and thus the workman proceeds, until the whole has acquired the appearance of a flat circular piece, consisting of a number of concentric undulations or folds, with the point in the centre. This is laid upon the plank, where the workman, keeping the piece wet with the liquor, pulls out the point with his fingers, and presses it down with his hand, at the same time turning it round on its centre in contact with the plank, till he has, by this means, rubbed out a flat portion equal to the intended crown of the hat. In the next place, he takes a block, to the crown of which he applies the flat central portion of the felt, and by forcing a string down the sides of the block, he causes the next part to assume the figure of the crown, which he continues to wet and work, until it has properly disposed itself round the block. The rim now appears like a slouched or puckered appendage round the edge of the crown; but the block being set upright on the plank, the requisite figure is soon given by working, rubbing, and extending this part. Water only is used in this operation of fashioning or blocking; at the conclusion of which it is pressed out by the blunt edge of a copper implement for that purpose.

"Previous to the dyeing, the nap of the hat is raised or loosened out with a wire brush, or carding instrument. The fibres are too rotten after the dyeing to bear this operation. The dyeing materials are logwood, and a mixture of the sulphates of iron and of copper, known in the market by the names of green copperas and blue vitriol. As the time of Mr Collinson was limited, and my attention, says Mr Nicholson, was more particularly directed to the mechanical processes, I did not go into the dye-house; but I have no doubt that the hats are boiled with the logwood, and afterwards immersed in the saline solution. I particularly asked whether galls were used, and was answered in the negative.

"The dyed hats are, in the next place, taken to the stiffening shop. One workman, assisted by a boy, does this part of the business. He has two vessels, or boilers, the one containing the grounds of strong beer, which costs seven shillings per barrel, and the other vessel containing melted glue, a little thinner than it is used by carpenters. Our author particularly asked, whether this last solution contained any other ingredient besides glue, and was assured that it did not. The beer grounds are applied in the inside of the crown to prevent the glue from coming through to the face, and also, as he supposes, to give the requisite firmness at a less expence than could be produced by glue alone. If the glue were to pass through the hat in different places, it might, he imagines, be more difficult to produce an even gloss upon the face in the subsequent finishing. The glue stiffening is applied after the beer grounds are dried, and then only upon the lower face of the flap, and the inside of the crown. For this purpose the hat is put into another hat, called a stiffening hat, the crown of which is notched, or slit open in various directions. These are then placed in a hole in a deal board,

Hat. board, which supports the flap, and the glue is applied with a brush.

“ The dry hat, after this operation, is very rigid, and its figure irregular. The last dressing is given by the application of moisture and heat, and the use of the brush and a hot iron, somewhat in the shape of that used by tailors, but shorter and broader on the face. The hat being softened by exposure to steam, is drawn upon a block, to which it is securely applied by the former method of forcing a string down from the crown to the commencement of the rim. The judgment of the workman is employed in moistening, brushing, and ironing the hat, in order to give and preserve the proper figure. When the rim of the hat is not intended to be of an equal width throughout, it is cut by means of a wooden, or perhaps metallic pattern; but as no such hats are now in fashion, Mr Nicholson saw only the tool for cutting them round. The contrivance is very ingenious and simple. A number of notches are made in one edge of a flat piece of wood for the purpose of inserting the point of a knife, and from one side or edge of this piece of wood there proceeds a straight handle, which lies parallel to the notched side, forming an angle somewhat like that of a carpenter's square. When the legs of this angle are applied to the outside of the crown, and the board lies flat on the rim of the hat, the notched edge will lie nearly in the direction of the radius, or line pointing to the centre of the hat. A knife being therefore inserted in one of the notches, it is easy to draw it round by leaning the tool against the crown, and it will cut the border very regular and true. This cut is made before the hat is quite finished, and is not carried entirely through; so that one of the last operations consists in tearing off the redundant part, which by that means leaves an edging of beaver round the external face of the flap. When the hat is completely finished, the crown is tied up in gauze paper, which is neatly ironed down. It is then ready for the subsequent operations of lining,” &c.

Our author concludes his valuable memoir on the fabrication of hats, with some observations on the probable gain or loss of employing machinery in the manufacture. These observations, as they are stated in the original paper, we recommend to the serious attention of every judicious hat-maker, who carries on his business on a large scale; for he will find them not the reveries of a rash speculatist, but the cool reflections of a real philosopher, who is at the same time no stranger to the arts of life. They suggest the following subjects of inquiry: Whether carding, which is rapidly and mechanically done, be inferior to bowing, which does not promise much facility for mechanical operation? Whether a succession of batts or cardings might be thrown round a fluted cone, which rapidly revolving, in contact with three or more cylinders, might perform the hardening, and even the working, with much more precision and speed than they are now done by hand? Whether blocking or shaping be not an operation extremely well calculated for the operation of one or more machines? Whether loose weaving and subsequent felting might not produce a lighter, cheaper, and stronger article? And how far the mechanical felting, which is not confined merely to the hairs of animals, might be applied to this art?

Before we dismiss this subject, it may be worth while

to state Mr Dunnage's method of making *water-proof hats*, in imitation of beaver, for which, in November 1794, he obtained a patent. It is as follows: Let a shag be woven, of such count in the reed, and cut over such sized wire, as will give the hats to be manufactured from it that degree of richness, or appearance of fur, which may be thought necessary. The materials of which this shag may be composed are various, and should be accommodated to different kinds of hats, according to the degree of beauty and durability to be given them, and the price at which they are designed to be sold; that is to say, silk, mohair, or any other hair that is capable of being spun into an end fine enough for the purpose, cotton, inkle, wool, or a mixture of any, or all the above materials, as may suit the different purposes of the manufacturer. Those answer best (says our author), which are made with two poles, either of Bergam, Piedmont, or Organzine silk, rising alternately, in a reed of about nine hundred count to eighteen inches wide, with three shoots over each wire. This method of weaving distributes the silk (as it may be put single into the harness), and prevents any ribby appearance which it might have if the silk were passed double, and the whole of the pole cut over each wire. This may be made either on a two or four thread ground of hard silk, shot with fine cotton, which he thinks preferable for shoot, to silk, inkle, or any other material, as it forms both a close and fine texture. An inferior kind of hats may be made from any of the before-mentioned materials, and with cheaper silk. This shag should be stretched on a frame, such as dyers use to rack cloth; then (having previously set the pile upright with a comb, to prevent its being injured or stuck together), go over the ground with thin size, laid on with a soft brush. For black, or dark colours, common size will do; with white, or any light colour, use isinglass, or a size made from white kid leather. These, or gum, or any other mucilaginous matter, which, without altering the colour, will prevent oil from getting through the ground so as to injure the pile, will answer the purpose. Take care not to apply more of any material, as a preparation, than may be fully saturated with oil or varnish, so that water will not discharge it from the ground. The size, or other glutinous matter, being dry, the pile must be teeseled, or carded with a fine card, till the silk is completely taken out of the twist or throwing, when it will lose its coarse shaggy look, and assume the appearance of a very fine fur. It must now be once more set upright with a comb, and you may proceed to lay on your water-proof material; this too may be varied according to circumstances. For black, or any dark colour, linseed oil well boiled with the usual driers, and thickened with a small quantity of any good drying colour, will do; for white, or very fine colours, poppy or nut oil, or copal or other varnishes, may be used. In this particular the manufacturer must judge what will best answer his purpose, taking care never to use any thing that will dry hard, or be subject to crack. Mr Dunnage has found good drying linseed oil preferable to any other thing which he has used, and, with the precaution of laying on very little the first time, it will not injure the finest colours. When the first coat of oil is dry, go over it a second and a third time, if necessary, till you are convinced the

Hat.

pores of the ground are fully closed up, and the stuff rendered impervious to water. It should now stand several days, till the smell is sufficiently gone off; and before it is taken from the frame, should be gone over with some ox-gall or lime-water, to take off the greasiness, which would otherwise prevent the stiffening from adhering to the oil. The material being now ready to be formed into hats, should be cut into proper shapes for that purpose. The crown should be made up over a block, with needle and silk, the oiled side outwards. The seams should then be rubbed with a piece of hard wood, bone, or ivory, to make them lie flat, and the edges of the stuff pared off very near the stitches, that no joint may appear on the right side. The seams should then be carefully gone over with the prepared oil, till every crevice or hole made by the needle is completely filled up, and the crown rendered perfectly water-proof. The crown may then be turned and stiffened, by sticking linen, leather, paper, or any other material that may be found to answer the purpose, to the inner or painted side, till it acquires about the same degree of stiffness, or resistance to the touch, as a good beaver. The mucilaginous matter which he used to attach the stiffening to the crown, and the upper and under parts of the brim to each other, was composed of one pound of gum-arabic or fenega, one pound of starch, and a half a pound of glue, boiled up with as much water as reduced the whole to the consistence of a thick paste. A greater or less proportion of any of these ingredients may be used, and other glutinous and adhesive substances may answer the same purposes; or drying-oils may be made use of, instead of this or other mucilage; or any of the resinous gums dissolved in oil or spirits; only it should be observed, in this case, the hats will require more time in the preparation, as the oily matter, unless exposed to the air, will not readily dry; but he found by experience that the above mentioned composition does not dry hard or brittle, but retains that pleasant flexibility which is agreeable to the touch, while it communicates to the other materials a sufficient degree of elasticity. Before the brim is perfectly dry, care should be taken to form a neck or rising round the hole where it is to be attached to the crown, by notching it round with a pair of scissars, and then forcing it over a block something larger than you have made the hole, so that the uncut stuff may turn up, under the lower edge of the crown, about a quarter of an inch. Before you join the crown and brim together, go over the outside of the neck of the brim, and the inside of the crown, as high as the neck will come (which should be about half an inch), with the prepared oil; and when they are nearly dry, so as to adhere to the finger on touching them, put the crown over the neck of the brim, and let them be sewed strongly together, taking care to sew down as little of the pile as possible, and using the same precaution of oiling, where the needle has been through, as was observed in making up the crown. The hat is now ready for dressing; which operation may be performed over a block, with a hot iron, brush, &c. in the same manner as those commonly called felts. When putting in the lining, be very careful to let the needle only take hold of the under surface of the brim; for should it perforate the upper one, the water will find its way through, and the hat be of no value. Though we

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have already declared how little we are acquainted with the operation of hat-making, we cannot help suggesting the inquiry, whether these water-proof hats might not be improved both in strength and beauty, by a slight felting before the application of the size by the brush. Such of them as are composed of wool or hair, or contain a mixture of these materials, are unquestionably susceptible of felting.

HAWKINS (Sir John), was the youngest son of a man who, though descended from Sir John Hawkins the memorable admiral and treasurer of the navy in the reign of Queen Elizabeth, followed at first the occupation of a house-carpenter, which he afterwards exchanged for the profession of a surveyor and builder. He was born in the city of London on the 30th day of March 1719; and after having been sent first to one school, and afterwards to a second, where he acquired a tolerable knowledge of Latin, he went through a regular course of architecture and perspective, in order to fit him for his father's profession of a surveyor. He was, however, persuaded, by a near relation, to abandon the profession of his first choice, and to embrace that of the law; and was accordingly articulated to Mr John Scott an attorney and solicitor in great practice. In this situation his time was too fully employed in the actual dispatch of business to permit him, without some extraordinary means, to acquire the necessary knowledge of his profession by reading and study; besides that, his master is said to have been more anxious to render him a good copying clerk, by scrupulous attention to his hand-writing, than to qualify him by instruction to conduct business. To remedy this inconvenience, therefore, he abridged himself of his rest, and rising at four in the morning, found opportunity of reading all the necessary and most eminent law writers, and the works of our most celebrated authors on the subjects of verse and prose. By these means, before the expiration of his clerkship, he had rendered himself a very able lawyer, and had acquired a love for literature in general, but particularly for poetry and the polite arts; and the better to facilitate his improvement, he occasionally furnished to the Universal Spectator, the Westminster Journal, the Gentleman's Magazine, and other periodical publications of the time, essays and disquisitions on several subjects. The first of these is believed to have been an Essay on *Swearing*; but the exact time of its appearance, and the paper in which it was inserted, are both unknown. It was, however, re-published some years before his death (without his knowledge till he saw it in print) in one of the newspapers. His next production was an Essay on *Honesty*, inserted in the Gentleman's Magazine for March 1739; and which occasioned a controversy, continued through the Magazines for several succeeding months, between him and a Mr Calamy, a descendant of the celebrated Dr Edmund Calamy, then a fellow-clerk with him.

About the year 1741, a club having been instituted by several amateurs of music, under the name of the Madrigal Society, to meet every Wednesday evening, and his clerkship being now out, he became a member of it, and continued so many years. Pursuing his inclination for music still farther, he became also a member of the Academy of Ancient Music, which used to meet every Thursday evening at the Crown and Anchor in the Strand, but since removed to Freemasons Hall;

and:

Hawkins. and of this he continued a member till a few years before its removal.

Impelled by his own taste for poetry, and excited to it by his friend Foster Webb's example, who had contributed to the Gentleman's Magazine many very elegant poetical compositions, he had, before this time, himself become an occasional contributor in the same kind, as well to that as to some other publications. The earliest of his productions of this species, now known, is supposed to be a copy of verses "To Mr George Stanley, occasioned by looking over some Compositions of his lately published," which bears date 19th February 1740, and was inserted in the Daily Advertiser for February 21. 1741; but, about the year 1742, he proposed to Mr Stanley the project of publishing, in conjunction with him, six cantatas for a voice and instruments, the words to be furnished by himself, and the music by Mr Stanley. The proposal was accepted, the publication was to be at their joint expence, and for their mutual benefit; and accordingly, in 1742, six cantatas were thus published, the five first written by Mr Hawkins, the sixth and last by Foster Webb; and these having succeeded beyond the most sanguine expectations of their authors, a second set of six more, written wholly by himself, was in like manner published a few months after, and succeeded equally well.

As these compositions, by being frequently performed at Vauxhall, Ranelagh, and other public places, and at many private concerts, had become favourite entertainments, many persons, finding the author also a modest well-informed young man of unexceptionable morals, were become desirous of his acquaintance. Among these was Mr Hare of Limehouse, a brewer, who being himself a musical man, and having met him at Mr Stanley's at musical parties, gave him an invitation to his house; and, to forward him in his profession, introduced him to a friend of his, Peter Storer of Highgate, Esq; which proved the means of making his fortune.

In the winter of the year 1749, Doctor, then Mr Johnson, was induced to institute a club to meet every Tuesday evening at the King's Head, in Ivy lane, near St Paul's. It consisted only of nine persons; and Mr Hawkins was one of the first members. About this time, as it is supposed, finding his father's house, where he had hitherto resided, too small for the dispatch of his business, now very much increasing, he, in conjunction with Dr Munckley, a physician with whom he had contracted an intimacy, took a house in Clements-lane, Lombard-street. The ground-floor was occupied by him as an office, and the first floor by the Doctor as his apartment. Here he continued till the beginning of 1753, when, on occasion of his marriage with Sidney, the youngest of Mr Storer's daughters, who brought him a considerable fortune, he took a house in Austin Friars, near Broad-street, still continuing to follow his profession of an attorney.

Having received, on the death of Peter Storer, Esq; his wife's brother, in 1759, a very large addition to her

fortune, he quitted business to Mr Clark, afterwards Alderman Clark, who had a short time before completed his clerkship under him, disposed of his house in Austin Friars, and purchased a house at Twickenham. Soon afterwards he bought the lease of one in Hatton-street, London, for a town residence.

From a very early period of his life he had entertained a strong love for the amusement of angling; and his affection for it, together with the vicinity of the river Thames, was undoubtedly his motive to a residence at this village. He had been long acquainted with Walton's Complete Angler; and had, by observation and experience, become himself a very able proficient in the art. Hearing, about this time, that Mr Moses Browne proposed to publish a new edition of that work, and being himself in possession of some material particulars respecting Walton, he, by letter, made Mr Browne an offer of writing, for his intended edition, Walton's Life. To this proposal no answer was returned, at least for some time; from which circumstance Mr Hawkins concluded, as any one reasonably would, that his offer was not accepted; and, therefore, having also learnt that Mr Browne meant not to publish the text as the author left it, but to modernize it, in order to file off the rust, as he called it, he wrote again to tell Mr Browne that he understood his intention was to sophisticate the text, and that therefore he, Mr Hawkins, would himself publish a correct edition. Such an edition, in 1760, he accordingly published in octavo with notes, adding to it a Life of Walton by himself, a Life of Cotton, the author of the second part, by the well-known Mr Oldys; and a set of cuts designed by Wale, and engraved by Ryland.

His propensity to music, manifested by his becoming a member and frequenter of the several musical societies before mentioned, and also by a regular concert at his house in Austin Friars, had led him, at the time that he was endeavouring to get together a good library of books, to be particularly solicitous for collecting the works of some of the best musical composers; and, among other acquisitions, it was his singular good fortune to become possessed by purchase of several of the most scarce and valuable theoretical treatises on the science any where extant, which had formerly been collected by Dr Pepusch. With this stock of erudition, therefore, he, about this time, at the instance of some friends, set about procuring materials for a work then very much wanted, a History of the Science and Practice of Music, which he afterwards published.

At the recommendation of the well-known Paul Whitehead, to the Duke of Newcastle, then Lord-Lieutenant for Middlesex, his name was, in 1761, inserted in the commission of the peace for that county; and having, by the proper studies, and a sedulous attendance at the sessions, qualified himself for the office, he became an active and useful magistrate in the county (A). Observing, as he had frequent occasion to do in the course of his duty, the bad state of highways, and

(A) When he first began to act, he formed a resolution of taking no fees, not even the legal and authorized ones, and pursued this method for some time, till he found that it was a temptation to litigation, and that every trifling ale-house quarrel produced an application for a warrant. To check this, therefore, he altered his mode, and received his due fees, but kept them separately in a purse; and at the end of every summer, before he left the country for the winter, delivered the whole amount to the clergyman of the parish, to be by him distributed among such of the poor as he judged fit.

Hawkins. and the great defect in the laws for amending and keeping them in repair, he set himself to revise the former statutes, and drew an act of parliament consolidating all the former ones, and adding such other regulations as were necessary. His sentiments on this subject he published in octavo, in 1763, under the title of "Observations on the State of Highways, and on the Laws for amending and keeping them in Repair;" subjoining, to them the draught of the act before mentioned; which bill being afterwards introduced into parliament, passed into a law, and is that under which all the highways in England are at this time kept repaired. Of this bill, it is but justice to add, that, in the experience of more than thirty years, it has never required a single amendment.

Johnson, and Sir Joshua, then Mr Reynolds, had, in the winter of this year (1763) projected the establishment of a club to meet every Monday evening at the Turk's Head, in Gerard-street; and, at Johnson's solicitation, Mr Hawkins became one of the first members.

An event of considerable importance engaged him, in the year 1764; to stand forth as the champion of the county of Middlesex, against a claim then for the first time set up, and so enormous in its amount as justly to excite resistance. The city of London finding it necessary to rebuild the gaol of Newgate, the expence of which, according to their own estimates, would amount to L.40,000, had this year applied to parliament, by a bill brought into the House of Commons, in which, on a suggestion that the county prisoners removed to Newgate for a few days previous to their trials at the Old Bailey, were as two to one to the London prisoners constantly confined there, they endeavoured to throw the burthen of two-thirds of the expence on the county, while they themselves proposed to contribute one-third only. This attempt the magistrates for Middlesex thought it their duty to oppose; and accordingly a vigorous opposition to it was commenced and supported under the conduct of Mr Hawkins, who drew a petition against the bill, and a case of the county, which was printed and distributed amongst the members of both houses of parliament. It was the subject of a day's conversation in the House of Lords; and produced such an effect in the House of Commons, that the city, by its own members, moved for leave to withdraw the bill. The success of this opposition, and the abilities and spirit with which it was conducted, naturally attracted towards Mr Hawkins the attention of his fellow-magistrates; and the chairman of the quarter sessions dying not long after, he was, on the 19th day of September 1765, elected his successor.

In the year 1771 he quitted Twickenham, and sold his house there to Mr Vaillant; and in the summer of the next year, for the purpose of obtaining, by searches in the Bodleian and other libraries, farther materials for his history of music, he made a journey to Oxford, carrying with him an engraver from London, to make drawings from the portraits in the music school.

On occasion of actual tumults or expected disturbances, he had more than once been called into service of great personal danger. When the riots at Brentford had arisen, during the time of the Middlesex election in the year 1768, he and some of his brethren attended to suppress them; and, in consequence of an expected riotous assembly of the journeymen Spitalfield weavers in

Moorfields in 1769, the magistrates of Middlesex, and he at their head, with a party of guards, attended to oppose them; but the mob, on seeing them prepared, thought it prudent to disperse. In these and other instances, and particularly in his conduct as chairman, having given sufficient proof of his activity, resolution, abilities, integrity, and loyalty, he, on the 23d of October 1772, received from his majesty the honour of knighthood.

In 1773, Dr Johnson and Mr Stevens published, in 10 vols 8vo, their first joint edition of Shakespeare, to which Sir John Hawkins contributed such notes as are distinguished by his name, as he afterwards did a few more on the republication of it in 1778. An address to the king from the county of Middlesex, on occasion of the American war, having, in 1774, been judged expedient, and at his instance voted, he drew up such an address, and, together with two of his brethren, had, in the month of October in that year, the honour of presenting it.

After sixteen years labour, he, in 1776, published, in five volumes quarto, his General History of the Science and Practice of Music; which, in consequence of permission obtained in 1773, he dedicated to the king, and presented it to him at Buckingham House on the 14th of November 1776, when he was honoured with an audience of considerable length both from the king and queen.

Not long after this publication, that is to say in November 1777, he was induced, by an attempt to rob his house, which, though unsuccessful, was made three different nights with the interval of one or two only between each attempt, to quit his house in Hatton-street; and, after a temporary residence for a short time in St James's Place, he took a lease of one, formerly inhabited by the famous Admiral Vernon, in the street leading up to Queen Square, Westminster, and removed thither.

By this removal he became a constant attendant on divine worship at the parish-church of St Margaret, Westminster; and having learnt, in December 1778, that the surveyor to the board of ordnance was, in defiance of a proviso in the lease under which they claimed, carrying up a building at the east end of the church, which was likely to obscure the beautiful painted glass window over the altar there, Sir John Hawkins, with the concurrence of some of the principal inhabitants, wrote to the surveyor, and compelled him to take down two feet of the wall, which he had already carried up above the sill of the window, and to slope off the roof of his building in such a manner, as that it is not only no injury, but, on the contrary, a defence to the window.

In the month of December 1783, Dr Johnson having discovered in himself symptoms of a dropsy, sent for Sir John Hawkins, and telling him the precarious state of his health, declared his desire of making a will, and requested him to be one of his executors. Sir John accepted the office; instructed the Doctor how to make his will; and on his death undertook to be his biographer, and the guardian of his fame, by publishing a complete edition of his works.

Not three months after the commencement of this undertaking, he met with the severest loss of almost any that a literary man can sustain, short of that of his friends or relations, in the destruction, by fire, of his library; consisting of a numerous and well-chosen collection.

Hawkins. lection of books, ancient and modern, in many languages, and on most subjects, which it had been the business of above 30 years at intervals to get together. Of this loss, great as it was in pecuniary value, and comprising in books, prints, and drawings, many articles that could never be replaced, he was never heard in the smallest degree to complain; but having found a temporary reception in a large house in Orchard-street, Westminster, he continued there a short time, and then took a house in the Broad Sanctuary, Westminster.

This event, for a short time, put a stop to the progress of his literary pursuits. As soon, however, as he could sufficiently collect his thoughts, he recommenced his office of biographer of Johnson; and completed his intention by publishing, in 1787, the life and works, in eleven volumes octavo, which he dedicated to the king.

With this production he terminated his literary labours; and having for many years been more particularly sedulous in his attention to the duties of religion, and accustomed to spend all his leisure from other necessary concerns in theological and devotional studies, he now more closely addicted himself to them, and set himself to prepare for that event, which he saw could be at no great distance; and the better to accomplish this end, in the month of May 1788, he, by a will and other proper instruments, made such an arrangement of his affairs as he meant should take place after his decease.

In this manner he spent his time till about the beginning of May 1789, when, finding his appetite fail him in a greater degree than usual, he had recourse, as he had sometimes had before on the same occasion, to the waters of the Islington Spa. These he drank for a few mornings; but on the 14th of that month, while he was there, he was, it is supposed, seized with a paralytic affection, as, on his returning to the carriage which waited for him, his servants perceived a visible alteration in his face. On his arrival at home, he went to bed, but got up a few hours after, intending to receive an old friend, from whom he expected a visit in the evening. At dinner, however, his disorder returning, he was led up to bed, from which he never rose, on the 21st of the same month, about two in the morning, dying of an apoplexy. He was interred on the 28th in the cloisters of Westminster Abby, in the north walk near the eastern door into the church, under a stone, containing, by his express injunctions, no more than the initials of his name, the date of his death, and his age; leaving behind him a high reputation for abilities and integrity, united with the well-earned character of an active and resolute magistrate, an affectionate husband and father, a firm and zealous friend, a loyal subject, and a sincere Christian.

Such is the character of him in the Biographical Dictionary, which we have neither right nor inclination to controvert. With none of his works are we acquainted but his edition of *Walton's Complete Angler*, and his *Life of Johnson*. The former is a very pleasing book; and in the latter are collected many interesting anecdotes of literature and literary men; but they are not well arranged, and the style of the composition is coarse and slovenly. Sir John, we doubt not, was a man of worth, and his reflections on the sentimental slang of Sterne and others, shew that he had

successfully studied human nature; but he certainly was not a man of general taste.

Heat.

HEAT. See in this Supplement, CHEMISTRY, Part I. chap. v. where we have endeavoured to establish the modern doctrine respecting *Caloric* or latent heat. In n^o 309, &c. of that article, we have given an account of Count Rumford's ingenious experiments, instituted with a view to determine whether or not caloric be a substance, and have stated our reasons for dissenting from his opinion. It has been suggested to us, however, by a friend, to whose judgment we are inclined to pay great deference, that it would be proper, in this place, to give the Count's arguments at full length, and in his own words; and the propriety of this is the more apparent, that in the supplementary article ELECTRICITY, we have hinted our own suspicions of the non-existence of an *electrical fluid*. The Count then reasons from his experiments in the following words:

"By meditating on the results of all these experiments, we are naturally brought to that great question which has so often been the subject of speculation among philosophers, namely, What is heat?—Is there any such thing as an *igneous fluid*?—Is there any thing that can with propriety be called caloric?"

"We have seen that a very considerable quantity of heat may be excited in the friction of two metallic surfaces, and given off in a constant stream or flux in *all directions*, without interruption or intermission, and without any signs of diminution or exhaustion.

"From whence came the heat which was continually given off in this manner in the foregoing experiments? Was it furnished by the small particles of metal detached from the larger solid masses on their being rubbed together? This, as we have already seen, could not possibly have been the case.

"Was it furnished by the air? This could not have been the case; for in three of these experiments, the machinery being kept immersed in water, the access of the air of the atmosphere was completely prevented.

"Was it furnished by the water which surrounded the machinery? That this could not have been the case is evident; *first*, because this water was continually *receiving heat* from the machinery, and could not at the same time be *giving to* and *receiving heat from* the same body; and, *secondly*, because there was no chemical decomposition of any part of this water. Had any such decomposition taken place (which indeed could not reasonably have been expected), one of its compound elastic fluids (most probably inflammable air) must at the same time have been set at liberty, and, in making its escape into the atmosphere, would have been detected; but though I frequently examined the water to see if any air bubbles rose up through it, and had even made preparations for catching them, in order to examine them if any should appear, I could perceive none; nor was there any sign of decomposition of any kind whatever, or other chemical process going on in the water.

"Is it possible the heat could have been supplied by means of the iron bar to the end of which the blunt steel borer was fixed? or by the small neck of gun-metal by which the hollow cylinder was united to the cannon? These suppositions appear more improbable even than either of those before mentioned; for heat was continually

Heat, continually going off or out of the machinery, by both these last passages, during the whole time the experiment lasted.

“And, in reasoning on this subject, we must not forget to consider that most remarkable circumstance, that the source of the heat generated by friction in these experiments appeared evidently to be inexhaustible.

“It is hardly necessary to add, that any thing which any insulated body or system of bodies can continue to furnish without limitation, cannot possibly be a material substance; and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of any thing capable of being excited and communicated in the manner the heat was excited and communicated in these experiments, except it be motion.

“But although the mechanism of heat should in fact be one of those mysteries of nature which are beyond the reach of human intelligence, this ought by no means to discourage us, or even lessen our ardour, in our attempts to investigate the laws of its operations. How far can we advance in any of the paths which science has opened to us, before we find ourselves enveloped in those thick mists which on every side bound the horizon of the human intellect? But how ample and interesting is the field that is given us to explore!

“Nobody, surely, in his sober senses has ever pretended to understand the mechanism of gravitation; and yet what sublime discoveries was our immortal Newton enabled to make, merely by the investigation of the laws of its action! The effects produced in the world by the agency of heat are probably just as extensive and quite as important, as those which are owing to the tendency of the particles of matter towards each other; and there is no doubt but its operations are in all cases determined by laws equally immutable.”

HELENA, or ST HELENA. In addition to the account of this island in the *Encyclopædia*, the following particulars from Sir George Staunton deserve a place in this *Supplement*, because some of them are important in themselves, while others correct one or two mistakes into which we had fallen, by adopting, implicitly, the narrative of Forster.

The circumference of St Helena measures somewhat less than twenty-eight miles. Along the whole coast to leeward, or to the northward, ships may anchor in perfect security in all seasons of the year, but the bank shelves so abruptly afterwards, that the anchorage, being in deep water, is insecure. The tide seldom rises above three feet and a half; but the surge of the sea is sometimes tremendous; and several accidents happened in approaching or quitting the shore, until a wharf was erected lately, which renders the arrival there, and departure from it, perfectly safe. In the immediate neighbourhood of the island, storms are little known, thunder is rarely heard, and lightning is seldom perceived.

The steep eminences which intervene between the valleys, that are the chief seats of population, render the communication from one part of this little spot to another slow and difficult. Planters on the windward side of the island consider a journey to the leeward, or seat of government, as a serious undertaking. Several of them take that opportunity of paying their respects to the governor, which is called there sometimes “going to court.” There are St Helena planters who have not travelled so far. At present, by order of the governor, there are signals so placed all over the island,

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as to give instant notice of the approach of vessels to any part of it.

In the *Encyclopædia*, it is said that peaches are the only European fruits which thrive in St Helena; but this appears to be a mistake. Several sorts of fruit trees imported into the island had been destroyed by a particular insect; but encouragement has been given for the cultivation of those which that mischievous animal is known to spare, such as the apple, for example, with all the varieties of which it is susceptible. The plantain and banana, or the two species of the *musa*, thrive also remarkably well. The ground is fertile, and in favourable seasons produces, in some instances, double crops within the year. Plantations, however, of cotton, indigo, or caues, were not found to answer; though some good coffee has been produced in it. A botanic garden has been established near the governor's country house. An intelligent gardener has been sent to take care of it by the company; and a vast variety of trees, plants, and flowers of different, and sometimes opposite climates, are already collected in it. The surrounding sea abounds in esculent fish; and seventy different species, including turtle, have been caught upon the coasts. Whales are seen in great numbers playing round the island, where it is supposed the southern whale fishery might be carried on to great national advantage.

The country is chiefly cultivated by blacks. Persons of that colour were brought in a state of slavery to it by its first European settlers; and it seldom happens that white men will submit to common work where there are black slaves to whom it may be transferred. These were for a long time under the unlimited dominion of their owners, until a representation of the abuses made of that power induced the India Company to place them under the immediate protection of the magistracy, and to enact various regulations in their favour; which have contributed to render them, in a great degree, comfortable and secure. These regulations may have hurt, at first, the feelings of the owners of slaves, but not their real interest; for it appears, that before their introduction there was a loss, upon an average, of about ten in a hundred slaves every year, to be supplied at a very heavy expence; whereas, under the present system, they naturally increase. All future importation of slaves into the island is prohibited.

Besides the blacks in a state of slavery, there are some who are free. The labour of these tending to diminish the value of that of slaves, the free blacks became once obnoxious to some slave owners; who had sufficient influence, in a grand jury, to prevent them as without visible means of gaining a livelihood, and liable to become burdensome to the community; but upon examination, it appeared that all free blacks of age to work were actually employed; that not one of them had been tried for a crime for several years, nor had any of them been upon the parish. They are now by the humane interposition of the company placed under the immediate protection of the government, and put nearly upon a footing with the other free inhabitants, who, when accused of crimes, have the privilege of a jury, as well as in civil causes.

The principal settlement of St Helena has the peculiar advantage of uniting the shelter of a leeward situation with the coolness of windward gales. The south-east wind blows constantly down the valley, rendering a residence in it pleasant as well as healthy.

Helicoid
||
Hinzuán.

The country is so fertile, and the climate so congenial to the human feelings, that perhaps it would be difficult to find out a spot where persons, not having acquired a relish for the enjoyments of the world, or already advanced in life, and surfeited with them, could have a better chance of protracting their days in ease, health, and comfort.

HELICOID PARABOLA, or the *Parabolic Spiral*, is a curve arising from the supposition that the common or Apollonian parabola is bent or twisted, till the axis come into the periphery of a circle, the ordinates still retaining their places and perpendicular positions with respect to the circle, all these lines still remaining in the same plane.

HELISPHERICAL LINE, is the Rhumb line in Navigation; being so called, because on the globe it winds round the pole helically or spirally, coming still nearer and nearer to it.

HENIOCHAS, or HENIOCHUS, a northern constellation, the same as Auriga, which see *Encycl.*

HERSCHEL, the name by which the French, and most other European nations, call the new planet discovered by Dr Herschel in the year 1781. Its mark or character is ♃. The Italians call it Ouranos, or Urania; but the English, the Georgian Planet, or Georgian Sidus.

HETERODROMUS VECTIS, or LEVER, in Mechanics, a lever in which the fulcrum, or point of suspension, is between the weight and the power; being the same as what is otherwise called a lever of the first kind.

HINZUAN, the proper name of one of the Comora islands, which by different writers of different nations has been called *Anzuame*, *Anjuan*, *Juanny*, and *Jobanna*, and which is described in the *Encyclopædia* under the name of St JOANNA. In that article, it is observed, that an anonymous writer has censured the descriptions of this island given by the Abbé Reynal and Major Rooke, as being not only exaggerated, but erroneous; neither the country being so picturesque as the former represents it, nor the inhabitants meriting the respectable character given of them by the latter.

There was not perhaps much propriety in admitting into such a work as the *Encyclopædia Britannica*, the anonymous censure of descriptions, authenticated by the names of respectable authors; but the best reparation which we can make to those authors is, to inform our readers, that their descriptions of Hinzuán are confirmed by Sir William Jones, whose testimony, we believe, no man will controvert. That accomplished scholar, who visited the island on his voyage to India, thus describes its appearance from the bay in which the ship rode at anchor.

“Before us was a vast amphitheatre, of which you may form a general notion by picturing in your minds a multitude of hills infinitely varied in size and figure, and then supposing them to be thrown together, with a kind of artless symmetry, in all imaginable positions. The back ground was a series of mountains, one of which is pointed, near half a mile perpendicularly high from the level of the sea, and little more than three miles from the shore: all of them richly clothed with wood, chiefly fruit trees, of an exquisite verdure. I had seen many a mountain of stupendous height in Wales and Switzerland, but never saw one before, round the bosom of which the clouds were almost continually rolling, while its green summit rose flourishing above

them, and received from them an additional brightness. Next to this distant range of hills was another tier, part of which appeared charmingly verdant, and part rather barren; but the contrast of colours changed even this nakedness into a beauty: nearer still were innumerable mountains, or rather cliffs, which brought down their verdure and fertility quite to the beach; so that every shade of green, the sweetest of colours, was displayed at one view by land and by water. But nothing conducted more to the variety of this enchanting prospect, than the many rows of palm trees, especially the tall and graceful *Areca*, on the shores, in the valleys, and on the ridges of hills, where one might almost suppose them to have been planted regularly by design. A more beautiful appearance can scarce be conceived, than such a number of elegant palms in such a situation, with luxuriant tops, like verdant plumes, placed at just intervals, and showing between them part of the remoter landscape, while they left the rest to be supplied by the beholder's imagination. The town of *Matsamúlo* lay on our left, remarkable at a distance for the tower of the principal mosque, which was built by Hahmah, a queen of the island, from whom the present king is descended: a little on our right was a small town, called *Bantáni*. Neither the territory of *Nice*, with its olives, date trees, and cypresses, nor the isles of *Hieres*, with their delightful orange groves, appeared so charming to me as the view from the road of *Hinzuán*.”

Sir William Jones, speaking of the inhabitants, takes notice of the *Lords*, *Dukes*, and *Princes*, of whom we have made mention after Major Rooke. “The frigate, (says he) was presently surrounded with canoes, and the deck soon crowded with natives of all ranks, from the high born chief, who washed linen, to the half-naked slave, who only paddled. Most of them had letters of recommendation from Englishmen, which none of them were able to read, though they spoke English intelligibly; and some appeared vain of titles, which our countrymen gave them in play, according to their supposed stations: we had *Lords*, *Dukes*, and *Princes*, on board, soliciting our custom, and importuning us for presents. In fact, they were too sensible to be proud of empty sounds, but justly imagined, that those ridiculous titles would serve as marks of distinction, and, by attracting notice, procure for them something substantial.” He speaks with great respect of the king, whose name was *Ahmed*, as well as of several chiefs whom he saw, and seems to have met with no man of rank on the island whose character was contemptible, but Selim the king's eldest son. For the behaviour of that prince, the old sovereign made the best apology that he could, while he privately assured the interpreter, that he was much displeased with it, and would not fail to express his displeasure. He concluded his conversation with a long harangue on the advantage which the English might derive from sending a ship every year from Bombay to trade with his subjects, and on the wonderful cheapness of their commodities, especially of their cowries. Ridiculous as this idea might seem, it showed (says Sir William) an enlargement of mind, a desire of promoting the interest of his people, and a sense of the benefits arising from trade, which could hardly have been expected from a petty African chief, and which, if he had been sovereign of Yemen, might have been expanded into rational projects proportioned to the extent of his dominions.

Hinzuán.

The master of the frigate learned from one of the chiefs a few curious circumstances concerning the government of *Hinzuán*; which he found to be a monar- chally limited by an aristocracy. The king, he was told, had no power of making war by his own authority; but if the assembly of nobles, who were from time to time convened by him, resolved on a war with any of the neighbouring islands, they defrayed the charges of it by voluntary contributions; in return for which, they claimed as their own all the booty and captives that might be taken. The hope of gain or the want of slaves is usually the real motive for such enterprises, and ostensible pretexts are easily found: at that very time, he understood they meditated a war, because they wanted hands for the following harvest. Their fleet consisted of sixteen or seventeen small vessels, which they manned with about two thousand five hundred islanders, armed with muskets and cutlasses, or with bows and arrows. Near two years before they had possessed themselves of two towns in *Mayáta*, which they still kept and garrisoned. The ordinary expences of the government were defrayed by a tax from two hundred villages; but the three principal towns were exempt from all taxes, except that they paid annually to the chief *Musí* a fortieth part of the value of all their moveable property; and from that payment neither the king nor the nobles claimed an exemption. The kingly authority, by the principles of their constitution, was considered as elective, though the line of succession had not in fact been altered since the first election of a sultan.

Sir William Jones concludes his remarks on this island with some reflections; of which, though they may be considered as digressive, we are persuaded our readers will approve of our extending the circulation.

“ We have lately heard of civil commotions in *Hinzuán*, which, we may venture to pronounce, were not excited by any cruelty or violence of Ahmed, but were probably occasioned by the insolence of an oligarchy naturally hostile to king and people. That the mountains in the *Comara* islands contain diamonds, and the precious metals, which are studiously concealed by the policy of the several governments, may be true, though I have no reason to believe it, and have only heard it asserted without evidence; but I hope, that neither an expectation of such treasures, nor of any other advantage, will ever induce an European power to violate the first principles of justice by assuming the sovereignty of *Hinzuán*, which cannot answer a better purpose than that of supplying our fleets with seasonable refreshment; and although the natives have an interest in receiving us with apparent cordiality, yet if we wish their attachment to be unfeigned and their dealings just, we must set them an example of strict honesty in the performance of our engagements. In truth, our nation is not cordially loved by the inhabitants of *Hinzuán*, who, as it commonly happens, form a general opinion from a few instances of violence or breach of faith. Not many years ago an European, who had been hospitably received and liberally supported at *Matsamudo*, behaved rudely to a young married woman, who, being of low degree, was walking veiled through a street in the evening; her husband ran to protect her, and resented the rudeness, probably with menaces, possibly with actual force; and the European is said to have given him a mortal wound with a knife

or bayonet, which he brought, after the scuffle, from his lodging. This foul murder, which the law of nature would have justified the magistrate in punishing with death, was reported to the king, who told the governor (I use the very words of Alwi, a cousin of the king's), that “ it would be wiser to hush it up.” Alwi mentioned a civil case of his own, which ought not to be concealed. When he was on the coast of Africa in the dominions of a very savage prince, a small European vessel was wrecked; and the prince not only seized all that could be saved from the wreck, but claimed the captain and the crew as his slaves, and treated them with ferocious insolence. Alwi assured me, that, when he heard of the accident, he hastened to the prince, fell prostrate before him, and by tears and importunity prevailed on him to give the Europeans their liberty; that he supported them at his own expence, enabled them to build another vessel, in which they sailed to *Hinzuán*, and departed thence for Europe or India: he shewed me the captain's promissory notes for furs, which to an African trader must be a considerable object, but which were no price for liberty, safety, and, perhaps, life, which his good, though disinterested, offices had procured. I lamented that, in my situation, it was wholly out of my power to assist Alwi in obtaining justice; but he urged me to deliver an *Arabic* letter from him, inclosing the notes, to the governor general, who, as he said, knew him well; and I complied with his request. Since it is possible, that a substantial defence may be made by the person thus accused of injustice, I will not name either him or the vessel which he had commanded; but, if he be living, and if this paper should fall into his hands, he may be induced to reflect how highly it imports our national honour, that a people, whom we call savage, but who administer to our convenience, may have no just cause to reproach us with a violation of our contracts.”

HIPS, in architecture, are those pieces of timber placed at the corners of a roof. These are much longer than the rafters, because of their oblique position. Hip means also the angle formed by two parts of the roof, when it rises outwards.

Hip-Roof, called also Italian roof, is one in which two parts of the roof meet in an angle, rising outwards: the same angle being called a valley, when it sinks inwards.

HIRCUS, in astronomy, a fixed star of the first magnitude, the same with capella.

HIRCUS is also used by some writers for a comet, encompassed as it were with a mane, seemingly rough and hairy.

HIRUDO. See *Encycl.* A new species of this insect was discovered in the South Sea by Le Martiniere, naturalist in Perouse's voyage of discovery. He found it buried about half an inch in a shark's liver, but could not conceive how it had got thither. It was something more than an inch long, of a whitish colour, and composed of several rings similar to those of the tænia. The superior part of its head was furnished with four small ciliated mamillæ, by which it took its food; under each mamilla on both sides was a small oblong pouch, in the form of a cup; and in the form of its *infrumenta cibaria*, it very nearly resembles the animal which has been supposed to be the cause of measles in swine. Both these species are referable to the genus *hirudo*, the characters of which, as given by Linnæus, stand (says Martiniere) in need of reformation.

Hinzuán

Hirudo.

Hirundo,
Hispaniola.

HIRUNDO ESCULENTA (see HIRUNDO, *Encycl.* n^o 3.), is thus described in the *Transactions of the Batavian Society in the Island of Java*, vol. iii. ; and the description confirms the sagacious conjecture of Mr Latham respecting the size of the bird, which the reader will find in our article referred to.

“The hirundo esculenta is of a blackish grey colour, inclining a little to green; but on the back to the tail, as well as on the belly, this blackish colour gradually changes into a mouse colour. The whole length of the bird from the bill to the tail is about four inches and a half, and its height from the bill to the extremity of the middle toe three inches and a quarter. The distance from the tip of the one wing to that of the other, when extended, is ten inches and a quarter. The largest feathers of the wings are about four inches in length. The head is flat; but, on account of the thickness of the feathers, appears round, and to be of a large size in proportion to the rest of the body. The bill is broad, and ends in a sharp extremity, bent downwards in the form of an awl. The width of it is increased by a naked piece of skin, somewhat like parchment, which, when the bill is shut, lies folded together; but which, when the bill opens, is considerably extended, and enables the bird to catch with greater ease, while on wing, the insects that serve it for food. The eyes are black, and of a considerable size. The tongue, which is not forked, is shaped like an arrow. The ears are flat, round, naked spots, with small oblong openings, and are entirely concealed under the feathers of the head. The neck is very short, as well as the legs and the bones of the wings. The thighs are wholly covered with feathers; and the very tender lower parts of the legs, and the feet themselves, are covered with a skin like black parchment. Each foot has four toes, three of which are before and one turned backwards. They are all detached from each other to the roots; and the middle one, together with the claw, is fully as long as the lower part of the leg. Each toe is furnished with a black, sharp, crooked claw of a considerable length, by which the animal can with great facility attach itself to crags and rocks. The tail is fully as long as the body together with the neck and the head. When expanded it has the form of a wedge, and consists of ten large feathers. The four first on each side are long; and, when the tail is closed, extend almost an inch beyond the rest. The other feathers decrease towards the middle of the tail, and are equal to about the length of the body.”

There is a variety of this species of hirundo, with a speckled breast, and white spots on the tail feathers; and this, though less numerous than the other, and indeed not found at all in Java, appears to have been the only hirundo esculenta known to Linnaeus. For an account of the eatable nests of these birds, and the manner of collecting them, see CAP and BURTON in this *Supplement*.

HISPANIOLA, or ST DOMINGO, the largest of the Antilles or Caribbee islands, has been described, as it existed prior to the French revolution, in the *Encyclopaedia*. Previous to the year 1789 the government of the French part of the island was administered by an officer called the Intendant, and a Governor-General, both nominated by the crown, and invested with authority for three years. Their powers were in some cases distinct, and in others united; but though these powers were extensive and almost absolute, the attention which

the old government of France paid to the character and rank of those persons whom it had placed over its foreign settlements, secured to the inhabitants of Hispaniola a very considerable share of happiness. In spite of what our restless innovators call political evils, signs of prosperity were everywhere visible; their towns were opulent, their markets plentiful, their commerce extensive, and their cultivation increasing.

Such was, in 1788, the state of the French colony, in the island of St Domingo; but in that eventful year, the flame, which had burst forth in Europe, spread itself to the West Indies. An association had been formed in France upon principles somewhat similar to those of our society for the abolition of the slave trade; but that association, which called itself *Amis des Noirs*, had much more dangerous designs than ours. Avowing its detestation of every kind of slavery, as well as of the African trade, and condemning those abettors of liberty who dared to declare themselves possessors of men, its members kept up an intimate and clandestine connection with those rich mulattoes who resided in France for their education, and laboured to convince them that neither their colour nor their *spurious birth* should make any civil or political distinction between them and the whites who were born in wedlock. To co-operate, as it were, with these factious and false doctrines, the National Assembly issued its famous declaration, in which it was maintained that all mankind are born, and continue free, and equal in their rights. The consequence of this was such as might have been expected. The mulattoes of Hispaniola, instructed in the French philosophy of the rights of man, broke out into rebellion; but not acting in concert, they were quickly overpowered.

The spirit, however, which had been excited among them, still continued to ferment; and the National Assembly of France, taking the state of the island into solemn consideration, decreed, by a great majority, that its intention had never been to intermeddle with the internal affairs of the colony; that their internal legislation was entirely their own; and that the legislature of the mother country would make no innovation, directly or indirectly, in the system of commerce in which the colonies were already concerned. However grateful this declaration might be to the whites of St Domingo, and in the then state of things however wise in itself, it occasioned discontent and remonstrances on the part of the factious friends of the negroes. They regarded it as an unwarrantable sanction of the African traffic, and a confession that the planters of Hispaniola were not colonists, but an independent people.

The colonists themselves, indeed, or rather their representatives, seem to have thought that by this decree they were rendered independent; for in their general assembly they passed an act debarring the king's delegate, the governor-general, from negating any of their future acts. This violent measure was far from giving universal satisfaction. The western parishes recalled their delegates, while those of Cape François renounced their obedience to the whole assembly, and petitioned the governor to dissolve it.

During these dissensions, the commander of a ship of the line, which lay in the harbour of Port-au-Prince, gave a sumptuous entertainment to the friends of the governor; on which account the seamen, who declared themselves in the interest of the assembly, thought fit to mutiny;

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Hispaniola mutiny; and the assembly, in return, voted their thanks to the mutineers. Some of their partizans, seizing at the same time a powder magazine, the governor declared them adherents to traitors, and called on all officers, civil and military, to bring them to punishment. This was the signal for civil insurrection; armed troops took the field on both sides; and war seemed inevitable, when the assembly resolved to repair in a body to France, and justify their past conduct.

In the mean time the *Amis des Noirs* contrived to excite the people of colour to rebellion. They initiated in the doctrine of equality and the rights of man one James Oge, then residing in Paris in some degree of affluence. They persuaded him to go to St Domingo, put himself at the head of his people, and deliver them from the oppression of the whites; and in order to evade the notice of government, they undertook to procure for him arms and ammunition in America. He embarked accordingly, July 1790, for New England with money and letters of credit; but notwithstanding the ezation of the *Amis des Noirs*, his designs were discovered by the French government, and his portrait was sent out before him to St Domingo. He landed on the island in October, and six weeks afterwards published a manifesto, declaring his intention of taking up arms, if the privileges of whites were not granted to *all persons without distinction*. He was joined by about 200 men of colour; and this little army of ruffians not only massacred the whites wherever they fell in with them in small numbers, but, by a still more unjustifiable mode of conduct, took vengeance on those of their own colour who refused to join their rebellious standard. They were, however, soon overpowered by the regular troops; and their leader, after disclosing, it is said, some important secrets, suffered the punishment due to his treason.

While these things were going on in the island, the members of the Colonial Assembly arrived at Paris, where they were received by the representatives of the French people with marked symptoms of aversion. The resolutions composing their famous decree were pronounced improper; their vote of thanks to the mutineers was declared criminal; they were themselves personally arrested; orders were given for a new assembly to be called; and the king was requested to augment the naval and military force then at St Domingo.

The National Assembly of France having decreed that every person twenty-five years old and upwards, possessing property, or having resided two years in the colony and paid taxes, should be permitted to vote in the formation of the colonial assembly, the people of colour very naturally concluded that this privilege was conferred upon them. Such, however, we believe, was not the meaning of the National Assembly; but Gregoire, with the other friends of the negroes, at last prevailed, and mulattoes born of free parents were pronounced to be not only worthy of choosing their representatives, but also eligible themselves to seats in the colonial assemblies. This decree sacrificed at once all the whites in the island to the people of colour; and the indignation which filled the minds of both the royal and the republican parties seemed to have united them in one common cause. They resolved to reject the civic oath; to confiscate the French property in the harbour, on which they actually laid an embargo; to pull down the national colours, and to hoist the British standard in their stead. The mulattoes in the mean time collected in ar-

med bodies, and waited with anxious expectation to see *Hispaniola* what measures the colonial assembly would adopt.

During these dissensions, the negro slaves, into whose minds had been sedulously instilled an opinion that their rights were equal to those of their masters, resolved to recover their freedom. On the morning of the 23d of August 1791, the town of the Cape was alarmed by a confused report that the slaves in the adjoining parishes had revolted; and the tidings were soon confirmed by the arrival of those who had narrowly escaped the massacre. The rebellion had broken out in the parish of Acul, nine miles from the city, where the whites had been butchered without distinction; and now the rebels proceeded from parish to parish, murdering the men, and ravishing the unfortunate women who fell into their hands. In a short time the sword was accompanied with fire, and the cane-fields blazed in every direction. The citizens now flew to arms, and the command of the national troops was given to the governor, whilst the women and children were put aboard the ships in the harbour for safety. In the first action the rebels were repulsed; but their numbers rapidly increasing, the governor judged it expedient to act solely on the defensive. In the space of two months it was computed that upwards of 2000 white persons perished; and of the insurgents, who consisted as well of mulattoes as of negroes, not fewer than 10,000 died by famine and the sword, and hundreds by the hands of the executioner.

When intelligence of these dreadful proceedings reached Paris, the Assembly began to be convinced that its equalising principles had been carried too far; and the famous decree, which put the people of colour on the same footing with the whites, was repealed. Three commissioners were likewise sent to the colony to restore peace between the whites and the mulattoes; but two of them being men of bad character, and none of them possessing abilities for the arduous task of extinguishing the flames of a civil war, they returned to France without accomplishing in any degree the object of their mission.

In the mean time the *Amis des Noirs* in the mother country had once more gained the ascendant in the National Assembly; and three new commissioners, Santhonax, Polverel, and Ailhaud, with 6000 chosen men from the national guards, were embarked for St Domingo. It was strongly suspected that the object of these commissioners was to procure unqualified freedom for all the blacks in the island; but they solemnly swore that their sole purpose was to establish the rights of the mulattoes, as decreed by the law which had been lately repealed. The whites therefore expected that a colonial assembly would be convoked; but instead of this the commissioners nominated twelve persons, of whom six had been members of the last assembly, and six were mulattoes, *Une Commission Intermediaire*, with authority to raise contributions on the inhabitants, the application of which, however, they reserved to themselves. The governor finding that the commissioners usurped all authority, complained that he was but a cypher in public affairs; his complaint was answered by an arrest upon his person, and he was sent a state prisoner to France.

The tyranny of the commissioners did not stop here. They overawed the members of the commission *intermediaire*, by arresting four of their number; and disagreeing among themselves, Santhonax and Polverel dismissed Ailhaud from their councils. War was by this time declared.

Hispaniola. declared between the mother country and Great Britain, and prudence compelled the government of France to take some care of the injured colony. Galbaud, therefore, a man of fair character, was appointed governor, and ordered to put the island in a state of defence against foreign invasion; but possessing West India property, which it seems was a legal disqualification for the office of governor, the commissioners disregarded his authority, and took up arms against him. Finding themselves likely to be worsted, they offered to purchase the aid of the rebel negroes, by the offer of a pardon for their past conduct, freedom in future, and the plunder of the capital. Two of the negro chiefs, more honourable than the French commissioners, spurned at the base proposal; but a third, after the governor had fled to the ships, entered the town with 3000 revolted negroes, and began an indiscriminate massacre. The miserable inhabitants fled to the shore, but their retreat was stopped by a party of mulattoes; and for two days the slaughter was incessant. The town was half consumed by fire; and the commissioners, terrified at the work of their own hands, fled for protection to a ship of the line, and thence issued a manifesto, which, while it tried to extenuate, evinced a consciousness of their guilt.

Thus was lost the finest island in the West Indies; an island which produced alone as much sugar as all the British West India possessions united; not to mention the coffee and indigo, which were in immense quantities cultivated in Hispaniola. Had it not been for the restless machinations of the *Amis des Noirs*, it does not appear that so general a revolt would have taken place among the slaves; for though the spirit of republicanism had found its way into the island, the republicans joined with the royalists to keep the negroes in proper subjection. The unsuccessful attempt which, at the request of the more respectable part of the inhabitants, the British government made to subdue the execrable commissioners and their adherents, is fresh in the memory of all our readers, and need not here be detailed at length. Suffice it to say, that after prodigies of valour, our troops were compelled, rather by disease than by the swords of the enemy, to abandon the island. Toussaint L'Ouverture, a black chief, converted it into an independent republic, and continued to govern it undisturbed, till the preliminaries of peace were signed between Britain and France in 1801. Immediately after that event, Bonaparte dispatched a fleet from Brest, with the permission of our government, carrying a considerable army under the command of general Le Clerc. Toussaint at first refused to submit. Several bloody actions were fought between the French troops and the blacks, in which the former were uniformly successful. The open country was soon abandoned by the negroes: several of Toussaint's generals submitted; and at last he himself was prevailed upon, by the address and the magnificent promises of Le Clerc, not only to throw down his arms, but to put himself into the power of the French general. For some days these promises were religiously observed; but a pretence was soon found for breaking them. Toussaint was stripped of his immense property, and sent prisoner to France. Thus was the colony recovered to France in a still shorter time than it had been lost. Since that event, nothing has transpired concerning the state of the island, or the regulations which the French find it necessary to make. But it is obvious, that a considerable period must elapse before it can be resto-

red to that state of prosperity which it formerly enjoyed.

HOLLOW, in architecture, a concave moulding, about a quarter of a circle, by some called a casement, by others an abacus.

Hollow-Tower, in fortification, is a rounding made of the remainder of two brisures, to join the curtain to the crillon, where the small shot are played, that they may not be so much exposed to the view of the enemy.

HOMODROMUS VECTIS, or *Lever*, in mechanics, is a lever in which the weight and power are both on the same side of the fulcrum as in the lever of the 2d and 3d kind; being so called, because here the weight and power move both in the same direction, whereas in the heterodromus they move in opposite directions.

HOOKE (Dr Robert) is said, in the account of him which is published in the *Encyclopædia*, to have laid claim to the inventions of others, and to have boasted of many of his own, which he never communicated. We will not presume to say that this charge is entirely groundless; but we know that it has been greatly exaggerated, and that many discoveries undoubtedly made by him have been claimed by others. Of this the reader will find one conspicuous proof under the article WATCH (*Encycl.*); and perhaps the following history of the inventions to which he laid claim may furnish another. It would be harsh to charge him with falsity in any of them; that is to say, to imagine that he either stole them from others, or did not *think*, at least, that he was an inventor. And, with respect to many of them, the priority of his claim is beyond dispute.

1656, Barometer, a weather glass.

1657, A escapement, for maintaining the vibration of a pendulum.—And not long after, the regulating or balance spring for watches.

1658, The double barrelled air-pump.—The conical pendulum.—His first employment of the conical pendulum was no less ingenious and scientific than it was original. He employed it to represent the mutual gravitation of the planets; a fact which he had most systematically announced. He had shewn that a force, perfectly analogous to gravity on this earth, operated on the surface of the moon and of Jupiter. Considering the numerous round pits on the surface of the moon, surrounded with a sort of wall, and having a little eminence in the middle, as the production of volcanoes, he inferred, that the ejected matter fell back again to the moon, as such matter falls back again to the earth. He saw Jupiter surrounded with an atmosphere, which accompanied him; and therefore pressed on him, as our air presses on the earth:—He inferred, that it was the same kind of power that maintained the sun and other planets in a round form. He inferred a force to the sun from the circulation round him, and he called it a *gravitation*; and said that it was not the earth which described the ellipse, but the centre of gravity of the earth and moon. He therefore made a conical pendulum, whose tendency to a vertical position represented the gravitation to the sun, and which was projected at right angles to the vertical plane; and shewed experimentally, how the different proportions of the projectile and centripetal tendencies produced various degrees of eccentricity in the orbit. He then added another pendulum, describing a cone round the first, while this described a cone round the vertical line, in order to see what point between them described the ellipse.

Hooke. ellipse. The results of the experiment were intricate and unsatisfactory; but the thought was ingenious. He candidly acknowledged, that he had not discovered the true law of gravitation which would produce the description of an ellipse *round the focus*, owing to his want of due mathematical knowledge; and therefore left this investigation to his superiors. Sir Isaac Newton was the happy man who made the discovery, after having entertained the same notions of the forces which connected the bodies of the solar system, before he had any acquaintance with Dr Hooke, or knew of his speculations.

1660, The engine for cutting clock and watch wheels.

—The chief phenomena of capillary attraction.—The freezing of water at a fixed temperature.

1663, The method of supplying air to a diving bell.

—The number of vibrations made by a musical chord.

1664, His *Micrographia* was, by the council of the Royal Society, ordered to be printed; but in that work are many just notions respecting respiration, the composition of the atmosphere, and the nature of light, which were afterwards attributed as discoveries to Mayow and others, who, though we are far from supposing that they stole their discoveries from Dr Hooke, were certainly anticipated by him.

1666, A quadrant by reflection.

1667, The marine barometer.—The gage for sounding unfathomable depths.

1668, The measurement of a degree of the meridian, with a view to determine the figure of the earth, by means of a zenith sector.

1669, The fact of the *conservatio virium vivarum*, and that in all the productions and extinctions of motion, the accumulated forces were as the squares of the final or initial velocities. This doctrine he announces in all its generality and importance, deducing from it all the consequences which John Bernoulli values himself so highly upon, and which are the chief facts adduced by Leibnitz in support of his doctrine of the forces of bodies in motion. But Hooke was perfectly aware of their entire correspondence with the Cartesian, or common doctrine, and was one of the first in applying the celebrated 39th proposition of Newton's *Principia* to his former positions on this subject, as a mathematical demonstration of them.

1673, That the catenaria was the best form of an arch.

1674, Steam engine on Newcomen's principle.

1679, That the air was the sole source of heat in burning: That combustion is the solution of the inflammable vapour in air; and that in this solution the air gives out its heat and light. That nitre explodes and causes bodies to burn without air, because it consists of this air, accompanied by its heat and light in a condensed or solid state; and air supports flame, because it contains the same ingredients that gunpowder doth, that is, a nitrous spirit: That this air dissolves something in the blood while it is exposed to it in the lungs in a very expanded surface, and when saturated with it, can no longer support life nor flame; but in the act of solution, it produces animal heat: That the arterial and venal blood differ on account of this something being wanting in one of them. In short, the fundamental doctrines of modern chemistry are systematically delivered by Dr Hooke in his *Micrographia*, published in 1664, and his *Lampas*, published in 1677.

Horne. 1680, He first observed the secondary vibrations of elastic bodies, and their connection with harmonic sounds. A glass containing water, and excited by a fiddlestick, threw the water into undulations, which were square, hexagonal, octagonal, &c. shewing that it made vibrations subordinate to the total vibration; and that the fundamental sound was accompanied by its octave, its twelfth, &c.

1681, He exhibited musical tones by means of toothed wheels, whirled round and rubbed with a quill, which dropped from tooth to tooth, and produced tones proportioned to the frequency of the cracks or snaps.

1684, He read a paper before the Royal Society, in which he affirms, that some years before that period, he had proposed a method of discoursing at a distance, not by sound, but by sight. He then proceeds to describe a very accurate and complete telegraph, equal, perhaps, in all respects to those now in use. But some years previous to 1684, M. Amontans had not invented his telegraph; so that, though the Marquis of Worcester unquestionably gave the first hint of this instrument, Dr Hooke appears to have first brought it to perfection. See TELEGRAPH, *Encycl.*; and a book, published 1726, entitled *Philosophical Experiments and Observations* of the late eminent Dr Robert Hooke.

We are indebted to him for many other discoveries of lesser note; such as the wheel barometer, the universal joint, the manometer, screw divided quadrant, telescopic sights for astronomical instruments, representation of a muscular fibre by a chain of bladders, experiments shewing the inflection of light, and its attraction for solid bodies, the curvilinear path of light thro' the atmosphere.

HORNE (George, D. D.), late Lord Bishop of Norwich, was a man of such amiable dispositions, primitive piety, and exemplary morals, that we wish it were in our power to do justice to his character. His life, it is true, has been already written, at considerable length, by two authors, possessed of erudition and of unquestionable integrity; but mere erudition is by no means sufficient to fit a man for discharging the duties of a biographer. It was not the learning of Johnson, but his sagacity, and intimate acquaintance with human nature, that placed him so far above his contemporaries in this department of literature.

Of Bishop Horne's biographers, one possessed; indeed, the great advantage of having lived in habits of intimacy with him from his boyish years. In the authenticity of his narrative, therefore, the fullest confidence may be placed: and that narrative we shall faithfully follow; reserving, however, to ourselves the liberty of sometimes making reflections on the various incidents recorded, widely different from those of the author.

George Horne was, in 1730, born at Otham in Kent, a village near Maidstone, giving the name to a parish, of which his father was the rector. He was the second of four sons; of whom the eldest died in very early life, and the youngest, who is still alive, succeeded his father both in the rectory of Otham and in that of Breda in the county of Sussex. He had likewise three sisters, of whose fortunes we know nothing.

Mr Horne, the father of the family, was of a temper so remarkably averse from giving pain or trouble upon any occasion, that he used to awake his son George, when an infant, by playing upon a flute, that

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the change from sleeping to awaking might be gradual and pleasant. Having been for some years a tutor at Oxford, he took upon himself the early part of the classical education of this favourite son; an office of which he was well qualified to discharge the duties. Under such an instructor, the subject of this memoir led a very pleasant life, and made a rapid progress in the Greek and Latin languages. By the persuasion of a friend, however, he was, at the age of thirteen, placed in the school of Maidstone, then under the care of a Mr Bye, eminent for his knowledge of ancient literature. And remaining with this gentleman two years, he added much to his stock of learning; and, among other things, a little elementary knowledge of the Hebrew tongue, which Mr Bye taught on the plan of Baxtorf. Though Dr Horne afterwards rejected that plan, he readily admitted, that the knowledge of it was of great advantage to him.

At the age of fifteen, he was removed from Maidstone school to University college Oxford, where his father had happily obtained for him a scholarship. At college his studies were, in general, the same with those of other virtuous and ingenious youths; while the vivacity of his conversation, and the propriety of his conduct, endeared him to all whose regard was creditable. About the time of his taking his bachelor's degree, he was chosen a fellow of Magdalen College; and soon afterwards, if not before, commenced author.

The history of his authorship is curious, and we shall give it at some length. While he was deeply engaged in the study of oratory, poetry, and every branch of polite literature, he was initiated by his faithful friend Mr Jones in the mysteries of Hutchinsonianism; but Mr Jones was not his preceptor. Indeed that gentleman informs us, that when he first communicated to Mr Horne the novelties with which his own mind was filled, he found his friend very little inclined to consider them; and had the mortification to see, that he was himself losing ground in Mr Horne's esteem, even for making the attempt to convert him. At this we are not to be much surpris'd. Mr Horne, though, by his biographer's account, no deep Newtonian, saw, or thought he saw, the necessity of a *vacuum* to the possibility of *motion*; and as we believe that every man, who knows the meaning of the words *motion* and *vacuum*, and whose mind is not biass'd in favour of a system, sees the same thing, it was not to be supposed, that a youth of sound judgment would hastily relinquish so natural a notion. By Mr Horne, however, it was at length relinquish'd. Mr Jones introduced him to Mr George Watson, a fellow of University college, whom he represents as a man of very superior accomplishments; and by Mr Watson Mr Horne was made a Hutchinsonian of such zeal, that at the age of nineteen, he implicitly adopted the wild opinion of the author of that system, that Newton and Clarke had formed the design of bringing the Heathen *Jupiter*, or Stoical *anima mundi*, into the place of the God of the universe. With such a conviction impress'd upon his mind, it is not wonderful that he should endeavour to discredit the system of Newton. This he attempted, by publishing a parallel between that system and the Heathen doctrines in the *Somnium Scipionis* of Cicero. That publication, which was anonymous, we have never seen; but Mr Jones himself admits it to have been exceptionable; and the ami-

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able author seems to have been of the same opinion, for he never republished it, nor, we believe, replied to the answers which it provoked.

He did not, however, desert the cause, but published, soon afterwards, a mild and serious pamphlet, which he called *A Fair, Candid, and Impartial State of the Case between Sir Isaac Newton and Mr Hutchinson*. Even of this pamphlet we have not been able to procure a sight; but Mr Jones assures us, that the author allows to Sir Isaac the great merit of having settled laws and rules in natural philosophy, and of having measured *forces* as a mathematician with sovereign skill; whilst he claims for Mr Hutchinson the discovery of the true physiological causes, by which, under the power of the Creator, the natural world is moved and directed.

If this be a fair view of the *state of the case*, it allows to Newton more than ever Newton claimed, or has been claimed for him by his fondest admirers; for the laws and rules, which he so faithfully followed in the study of philosophy, were not settled by him, but by the illustrious Bacon. With respect to the *true causes* here mentioned, we have repeatedly had occasion, during the course of this Work, to declare our opinion, that all men are equally ignorant of them, if they be considered as any thing distinct from the general *laws* by which the operations of nature are carried on. To the discovery of other physiological causes, Newton, in his greatest work, made indeed no pretension; but it may be worth while, and can hardly be considered as a digression, to consider what are the pretensions of Hutchinson, to which Messrs Horne and Jones gave so decided a preference.

Mr Hutchinson himself writes so obscurely, that we dare not venture to translate his language into common English, lest we should undesignedly misrepresent his meaning; but according to Mr Jones, who has studied his works with care, his distinguishing doctrine in philosophy is, that "The forces, of which the Newtonians treat, are not the forces of nature; but that the world is carried on by the action of the elements on one another, and all under God." What is here meant by the elements, we are taught by another eminent disciple of that school. "The great agents in nature, which carry on all its operations, are certainly (says Mr Parkhurst) the *fluid* of the heavens; or, in other words, the fire at the orb of the sun, the light issuing from it, and the spirit or gross air constantly supporting, and concurring to the actions of the other two." (See *CHERUBIM* in this *Supplement*). Mr Horne adopted this system in preference to the Newtonian; because, says his biographer, "It appeared to him nothing better than raving, to give active powers to matter, supposing it capable of acting where it is not; and to affirm, at the same time, that all matter is inert, that is, inactive; and that the *Deity* cannot act but where he is *present*, because his *power* cannot be but where his *substance* is."

That much impious arrogance has been betrayed, not by Newtonians only, but by philosophers of every school, when treating of the *modus operandi* of the *Deity*, we feel not ourselves inclined to controvert; but we never knew a well-informed Newtonian, who spoke of the active powers of matter but in a metaphorical sense; and such language is used, and must be used, by

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Horne. the followers of Hutchinson. Mr Jones speaks of the *action* of the elements; and Mr Parkhurst calls the fluid of the heavens, which, according to him, consists of fire, light, and air, *agents*; but it would surely be uncandid to accuse these two pious men of *animating* the elements, though we know that *action* and *activity*, in the literal sense of the words, can be predicated only of living beings. With respect to giving active powers to matter, therefore, the followers of Hutchinson rave just as much as those of Newton; and we see not the raving of either in any other light than as the necessary consequence of the poverty of language.

But the Newtonian makes matter act upon matter at a distance! No; the genuine Newtonian does not make matter act (in the proper sense of the word) at all; but he believes, that God has so constituted matter, that the motions of different masses of it are affected by each other at a distance; and the Hutchinsonian holds the very same thing. As this celestial fluid of Mr Parkhurst's consist; partly of air, we know, by the test of experiment, that it is elastic. The particles of which it is composed are therefore distant from each other; and yet they resist compression. How does the Hutchinsonian account for this fact? Perhaps he will say, that as matter is in itself equally indifferent to motion and rest, God has so constituted the particles of this fluid, that though they possess no innate power or activity of their own, they are affected by each other at a distance, in consequence of his fiat at the creation. This we believe to be the only solution of the difficulty which can be given by man; but it is the very answer given by the Newtonians to those who object to them the absurdity of supposing matter to be affected by matter at a distance. That the motions of the heavenly bodies are affected by the presence of each other is a fact, say they, which appears incontrovertible. "We have ascertained with precision the laws by which these motions are regulated; and without troubling ourselves with the true physiological causes, have demonstrated the agreement of the phenomena with the laws. The interposition of this celestial fluid removes not a single difficulty with which our doctrine is supposed to be clogged. To have recourse to it can therefore serve no purpose, even were the phenomena consistent with the nature of an elastic fluid considered as a physical cause; but this is not the case. It is demonstrable (see *ASTRONOMY* and *DYNAMICS* in this *Suppl.*) that the motions of the heavenly bodies are not consistent with the mechanism of an elastic fluid, considered as the cause of these motions; and therefore, whether there be such a fluid or not diffused through the solar system, we cannot allow that it is the great agent in nature by which all its operations are carried on."

Such might be the reasoning of a well-informed Newtonian in this controversy; and it appears so conclusive against the objections of Hutchinson to the Newtonian forces, as well as against the agents which he has substituted in their stead, that some of our readers may be disposed to call in question the soundness of that man's understanding who could become a Hutchinsonian so zealous as Mr Horne. But to these gentlemen we beg leave to reply, that the soundest and most upright mind is not proof against the influence of a system, especially if that system has novelty to recommend it, and at the same time consists of parts, of which, when taken sepa-

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rately, many are valuable. Such was the system of Hutchinson when adopted by Mr Horne. It was then but very little known; it could be studied only through the medium of Hebrew literature, not generally cultivated; and that literature, to the cultivation of which Mr Hutchinson had given a new and a better turn, is in itself of the utmost importance. Let it be observed, too, that the Hutchinsonians have, for the most part, been men of devout minds, zealous in the cause of Christianity, and untainted by Arianism, Socinianism, and the other heresies which have so often divided the church of Christ:—and when all these circumstances are taken into consideration, it will not be deemed a proof of any defect in Mr Horne's understanding, that in early life he adopted the *whole* of a system, of which some of the parts contain so much that is good; especially when it is remembered, that at *first view* the agency of the celestial fluid appears so plausible, that for a time it seems to have imposed upon the mind of Newton himself.

But the truth is, that Mr Horne was at no period of his life a thorough-paced Hutchinsonian. It is confessed by Mr Jones, "that Mr Hutchinson and his admirers laid too great a stress on the evidence of Hebrew etymology; and that some of them carried the matter so far, as to adopt a mode of speaking, which had a nearer resemblance to cant and jargon than to sound sense and sober learning. Of this (continues he) Mr Horne was very soon aware; and he was in so little danger of following the example, that he used to display the foibles of such persons with that mirth and good humour," which he possessed in a more exquisite degree than most men. This seems to be complete evidence that he was never a friend to the etymological part of the system; and the present writer can attest, that, in the year 1786, he seemed by his conversation to have lost much of his conviction of the agency of the celestial fluid. He continued, indeed, to study the Hebrew Scriptures on the plan of Mr Hutchinson, unincumbered with the Masoretic points, or with rabbinical interpretations; and the fruits of his studies are in the hands of the religious public, in works which, by *that* public, will be esteemed as long as their language is understood.

Hitherto Mr Horne was a layman, but he interested himself in every thing connected with religion, as much as the most zealous dignitary of the church; and considering the *naturalization* of the Jews as a measure at least indecent in a Christian country, he published, in an evening paper, a series of letters on that subject, both when the Jew-bill was depending, and after it had passed the house. The letters were anonymous; but they attracted much notice, and many groundless conjectures were made respecting their author. To the real author, the measure which they opposed was so very obnoxious, that he refused to dine at the table of a friend, only because the son-in-law of Mr Pelham was to be there. And he was not much more friendly to the marriage-act than to the Jew-bill. If he considered the one as disgraceful to religion, he probably thought that the other, with its numerous clauses, might be made a snare for virtue.

The time now approached when he was to take holy orders, which to him was a very serious affair; and when he gave an account of his ordination to an inti-

Horne. mate friend, he concluded the letter with the following reflections, which, even in an abstract like this, it would be unpardonable to omit :

“ May he, who ordered Peter three times to *feed his lambs*, give me grace, knowledge, and skill, to watch and attend to the flock which he purchased upon the cross, and to give rest to those who are under the burden of sin and sorrow. It hath pleased God to call me to the ministry in very troublesome times indeed, when a lion and a bear have broken into the fold, and are making havoc among the sheep. With a firm, though humble confidence, do I purpose to go forth ; not in my own strength, but in the strength of the Lord God ; and may he prosper the work of my hands ! ” This was in the year 1753, when the pious author was hardly 23 years of age ; and he had not been many months in orders, when one of the most celebrated preachers in the metropolis pronounced, that “ George Horne was, without exception, the best preacher in England. ”

In the year 1756, he was again involved in controversy. A pamphlet had been published at Oxford, supposed by Mr Kennicott, who afterwards gained such fame as a collector of Hebrew manuscripts, entitled *A Word to the Hutchinsonians*, in which Mr Horne was personally struck at. To this work our author replied in a small tract, called *An Apology for certain Gentlemen in the University of Oxford, Aspersed in a late Anonymous Pamphlet* ; and whatever may be thought of the question at issue, all men must admire the temper with which the apologist conducted himself under very great provocation.

But it was not about Hutchinsonianism alone that these two illustrious men were doomed to differ. Mr Horne took a decided part against Mr Kennicott's proposal for collating the text of the Hebrew bible, with such manuscripts as could be found, for the purpose of *reforming the text*, and preparing it for a new translation into the English language ; and in the year 1760, he published *A View of Mr Kennicott's Method of Correcting the Hebrew Text, with three Queries formed thereon, and humbly submitted to the Christian world*. That his alarm was on this occasion too great, experience has shewn ; but that it was not groundless, is evident from the *View*, in which the reader will find above 20 instances from Mr Kennicott's dissertations (see KENNICOTT, *Enycl.*), to shew what an inundation of licentious criticism was breaking in upon the sacred text. Indeed there is reason to believe, that this tract, together with another on the same side of the question by Dr Rutherford of Cambridge, contributed to repress the collector's rashness, and to make the Bible of Dr Kennicott the valuable work which we find it. Be this as it may, such was the moderation of the Drs Kennicott and Horne, that though their acquaintance commenced in hostility, they at length contracted for each other a friendship, which lasted to the end of their lives, and still subsists between their families.

In what year Mr Horne was admitted to the degree of D. D. and when he was chosen president of his college, Mr Jones has not informed us ; but, if our memory does not deceive us, he had obtained both these preferments when, in the year 1772, he gave to the public a small work, 8vo, entitled *Considerations on the*

Life and Death of St John the Baptist. This tract was the substance of a course of sermons, which he had many years before, in conformity to an established custom at Magdalen College, preached before the university of Oxford. Mr Jones, speaking of it, says, that “ he is persuaded there was no other man of his time, whose fancy as a writer was bright enough, whose skill as an interpreter was deep enough, and whose heart as a moralist was *pure* enough, to have made him the author of that little work. ” By most readers this strain of panegyric will be thought extravagant, and of course it will defeat its own purpose ; but the work is certainly a work of merit.

In the year 1776, when the author was vice-chancellor, was published, in two volumes 4to, Dr Horne's Commentary on the Psalms. It is a work of which very different opinions have been formed, though it was the result of the labour of twenty years. That it will always be a favourite companion of the devout Christian, we are as much inclined to believe as Mr Jones ; but we cannot, without belying our own judgment, say that it appears to us calculated to produce much general good in an age like the present. Granting it to be true, which we believe will not be granted without some exceptions, that Clarke, and Hoadley, and Hare, and Middleton, and Warburton, and SHERLOCK, and SOUTH, and WILLIAM LAW, and Edmund Law, had turned the public attention, of which they had got the entire command, too much to the *letter* of the Bible to the neglect of the *spirit* of it ; should not Dr Horne, after the example of St Paul, have let in the light gradually upon such weak organs as those of the public thus diseased, rather than pour it upon them at once in a flood of splendor. The apostle “ fed his Corinthian converts with milk and not with meat ” when he found them unable to bear the latter food ; and there is reason to suspect that the carnal followers of Warburton, and Sherlock, and South, were unable to bear, at once, such strong meat, as that which makes the fifteenth psalm a portrait of our Saviour. Indeed, we think it not improbable that the mind of Sherlock would have recoiled with horror from the very conception of the *possibility* of Jesus Christ “ swearing to his neighbour and disappointing him, ” though that conception must have passed through a mind which was certainly as pure as his. The commentary, however, though truth thus compels us to say that, in our opinion, it is far from perfect, is certainly a work of great learning, great genius, and fervent piety, and such as the devout Christian will peruse again and again with much advantage.

Dr Horne's next work was of a different kind, and, we think, of a superior order. In the year 1776 was published a letter of Dr Adam Smith's, giving an account of the death of Mr David Hume. The object of the author was to shew that Mr Hume, notwithstanding his sceptical principles, had died with the utmost composure, and that in his life, as well as at his death, he had conducted himself as became one of the wisest and best men that ever existed. The letter is very much laboured, and yet does no honour either to the author or his friend. It could not represent Mr Hume as supporting himself under the gradual decay of nature with the hopes of a happy immortality ; but it might have represented him as taking refuge, with other infidels, in the eternal sleep of death. This, though but a gloomy prospect, would

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not have been childish; but the hero of the tale is exhibited as talking like a school-boy of his conferences with Charon, and his reluctance to go into the Stygian ferry-boat, and as consoling himself with the thought of leaving all his friends, and his brother's family in particular, in great prosperity!!! The absurdities of this letter did not escape the watchful and penetrating eye of Dr Horne; and as he could not mistake its object, he held it up to the contempt and scorn of the religious world in *A Letter to Adam Smith, L. L. D. on the Life, Death, and Philosophy of his Friend David Hume, Esq.*, by one of the People called Christians. The reasoning of this little tract is clear and conclusive, while its keen, though good humoured wit is inimitable; and it was, some years afterwards, followed by a series of *Letters on Infidelity*, composed on the same plan, and with much of the same spirit. This small volume, to the second edition of which the letter to Dr Smith was prefixed, is better calculated than almost any other with which we are acquainted, to guard the minds of youth against the insidious strokes of infidel ridicule, the only dangerous weapon which infidelity has to wield.

When the letters on infidelity were published, their author had for some time been Dean of Canterbury, where he was beloved by the chapter and almost adored by the citizens. He was a very frequent preacher in the cathedral and metropolitical church, where the writer of this short sketch has listened to him with delight, and seen thousands of people of very various descriptions hang with rapture on his lips. As a preacher indeed he excelled; and notwithstanding the shortness of his sight, which deprived him of some of the graces of a pulpit orator, such were the excellence of his matter, the simple elegance of his style, and the sweetness of his voice, that, when at the primary visitation of the present archbishop, he preached his admirable sermon on the *Duty of Contending for the Faith*, the attention of more than 2000 people was so completely fixed, that the smallest noise was not to be heard through the whole crowded choir. Of the importance of preaching, and of the proper mode of performing that duty, he had very just notions; and though he never had himself a parochial cure of souls, it was the desire and pleasure of his life to make himself useful in the pulpit wherever he was, whether in town or in the most obscure corner of the country. Four or five volumes of his sermons have been published since his death.

In the year 1787 he published, under the name of an undergraduate of the university of Oxford, a letter to Dr Priestley, in which he made that oracle of Socinianism almost as ridiculous as, in the letter to Dr Smith, he had formerly made the hero of modern scepticism.

The merits of Dr Horne, which had made him president of Magdalen College, a king's chaplain, and dean of Canterbury, raised him, we think, in the year 1790, to the see of Norwich; and he had soon an opportunity of shewing that he had not lost sight of his spiritual character in the splendour of the peer of parliament. The Scotch Episcopalians had for some time been soliciting the legislature to repeal certain penal laws of uncommon severity, under which they had groaned for upwards of forty years; but they found it a work of no little difficulty to make the equity of their claim generally understood*. In removing this difficulty no man was more assisting to them than the Dean of Canter-

bury, to whom their religious and political principles were well known; and he continued his assistance after he was bishop of Norwich. Indeed the whole bench shewed, on this occasion, a zeal for the interests of true religion every way becoming their character of Christian bishops; and after Dr Horne was removed to a better world, the Scotch Episcopalians found among his surviving brethren friends as zealous and active as he.

Dr Horne, though a very handsome man, was not naturally of a strong constitution; and from the disadvantage of being uncommonly near-sighted, he had not been able to increase its strength by the practice of any athletic exercise. The only amusement in which he took delight was agreeable conversation; and his life was therefore what is called sedentary. The consequence of this was, that the infirmities of age came fast upon him; and when the design was formed of making him a bishop, he felt himself little inclined to undertake the charge of so weighty an office. He was, however, prevailed upon to accept of the see of Norwich; but he enjoyed his new dignity for a very short period, if he can with truth be said to have enjoyed it at all. His health declined rapidly; and, in the autumn of 1791, he suffered, while on the road from Norwich to Bath, a paralytic stroke, the effects of which he never recovered. He lingered a month or two, with such apparent changes in the state of his health as sometimes gave delusive hopes to his family, till the 17th of January 1792, when he died in the 62d year of his age, with those hopes which can be excited only by the consciousness of a well spent life, and by a firm trust in the promises of the gospel.

In this short sketch of the life of bishop Horne we have taken the liberty to express our dissent from some of his opinions, and to state the reasons on which that dissent rests. By himself we know that this part of our conduct would have been applauded; but it is possible that by some of his friends it may be deemed disrespectful to his memory. To these gentlemen we beg leave to observe, that if Johnson made the praise of *Kyrl*, Pope's Man of Ross, really more solid by making it more credible, it will be difficult to persuade us that we have done any injury to Dr Horne's fame by avoiding the extravagant panegyric of those who seem to have considered him as a man exempted from error. He was first induced to favour the Hutchinsonians because he thought he perceived danger to religion in the Newtonian doctrines of attraction and repulsion; and we very readily admit that many Newtonians, not understanding the doctrines of their master, have expressed themselves in such a manner as could not render a religious man partial to their system. But from the dangers of mistake, no system, whether religious or philosophical, was ever free; and the atheistical purposes which the agency of ethers and celestial fluids has lately been made to serve, must induce every man of piety to pause before he admit such agency. Dr Horne lived to witness some of its pernicious effects; and we have reason to believe that they made a due impression on his mind; but he spent his latter years, as indeed he had spent the greater part of his life, in nobler pursuits than the study of human science; he spent them in the proper employments of a Christian, a clergyman, and a bishop. His faith was founded on a rock; and it was that genuine faith which worketh by love; for though his preachers

* See SCOTCH EPISCOPALIANS in this Supplement.

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were rich, his charity kept pace with them; and it has been proved that, notwithstanding his proper economy, he hoarded not one shilling of his annual income. This was an elevation of character above all literary, above all philosophical fame. The author of this article had the honour to be known to Dr Horne, to enjoy, if he mistook not, a share in his friendship, and to correspond with him regularly for many years; and there is not one of his rational admirers who merely admits the truth of the character given of him by Dr Thurlow late bishop of Durham when succeeding him in the office of proctor in the University. "As to the last proctor (said he) I shall speak of him but in few words, for the truth of which I can appeal to all that are here present. If ever virtue itself was visible and dwelt upon earth, it was in the person who this day lays down his office."

Soon after he was advanced to the presidentship of Magdalen college, this great and good man married the only daughter of Philip Burton, Esq; a gentleman of considerable fortune. By this lady he had three daughters, of whom the eldest was married to a clergyman a short time before the death of her father, and the two younger were, in 1796, residing with Mrs Horne in Hertfordshire.

HOROGRAPHY, the art of making or constructing dials; called also dialing, horologigraphy, gnomonica, sciatherica, photosciatherica, &c.

HOROPTER, in optics, is a right line drawn through the point where the two optic axes meet, parallel to that which joins the centres of the two eyes, or the two pupils.

HORSE-SHOE, in fortification, is a work sometimes of a round, sometimes of an oval figure, inclosed with a parapet, raised in the ditch of a marshy place, or in low grounds; sometimes also to cover a gate; or to serve as a lodgment for soldiers, to prevent surprises, or relieve an over-tedious defence.

HOVEN is a word of the same import with *raised, swelled, tumefied*. It is particularly applied to black cattle and sheep, when from eating too voraciously of clover, or any other succulent food, they become swollen. Such cattle are, in the language of the farmer, called

HOVEN-Cattle; and the beast, whether bullock or sheep, which is hoven, when left without relief, dies in half an hour. The cause of the disease is the extra-quantity of air taken down with that kind of food, which, in its passage from the paunch upwards, forces the broad leaves of the clover before it, till they close up the passage at the entrance of the paunch, and prevent the wind from going upwards in its regular course. The usual method of relief is to stab the animal in the paunch; an operation which is always dangerous, and has often proved fatal. It was therefore, with good reason, that the Society for the Encouragement of Arts, Manufactures, and Commerce, voted a bounty of fifty guineas to Mr Richard Eagar of Grassham farm, near Guildford, for making public a very simple method practised by him for the cure of hoven-cattle. It is this; "let the grazier or farmer have always ready smooth knobs of wood, of different sizes, fixed to the end of a flexible cane, which for oxen should be at least six feet long, and for sheep three feet. When a beast is hoven, let one person take hold of him by the nostril

and one horn; let another hold his tongue fast in one hand, putting the cane down his throat with the other. Be careful not to let the animal get the knob of the cane between his grinders: observe also to put the cane far enough down; the whole length will not injure. You will find the obstacle at the entrance of the paunch: push the cane hard, and when you perceive a smell to come from the paunch, and the animal's body to sink, the cure is performed, and Nature will act for itself."

This method, we doubt not, will prove successful; but might not the purpose be as well, if not better, effected, by using, instead of the cane and knob, a piece of thick stiff rope, which, in many places of Scotland, is employed to force down turnips or potatoes when they stick in the throat of a bullock?

HOUGHTON (—) is a man to whom the science of geography is so much indebted, that we are almost ashamed to confess that we know not his Christian name, the place where he was born, or the age at which he died. He had been a captain in the 69th regiment, and in the year 1779 had acted under General Rooke as fort-major in the island of Goree. Hearing, some time in the year 1789, or perhaps earlier, that the African association wished to penetrate the Niger by the way of Gambia, he expressed his willingness to undertake the execution of their plan. For this task he was peculiarly fitted. A natural intrepidity of character which seemed inaccessible to fear, and an easy flow of constitutional good humour, which even the roughest accidents of life were not able to subdue, formed him for exploring the country of relentless savages; whilst the darkness of his complexion was such, that he scarcely differed in appearance from the Moors of Barbary, whose dress in travelling he intended to assume.

His instructions from the association were, to ascertain the course, and, if possible, the rise and termination of the Niger; and after visiting the cities of Tombuctoo and Houssa (see these articles in this *Supplement*); to return by the way of the desert, or by any other route which the circumstances of his situation at the time might recommend to his choice.

Having left England on the 16th of October 1790; he arrived at the entrance of the Gambia on the 10th of November, and was kindly received by the king of Barra, who remembered the visit which the major had formerly paid him from the island of Goree; and who now, in return for a small present of the value of 20s, cheerfully tendered protection and assistance as far as his dominion or influence extended.

An offer from the master of an English vessel employed in the trade of the river, enabled the Major, and the interpreter he had engaged on the coast, to proceed to Junkiconda; where he purchased from the natives a horse and five asses, and prepared to pass with the merchandise which constituted his travelling fund, to Medina, the capital of the small kingdom of Woolli.

Fortunately for him, a few words, accidentally dropped by a negro woman in the Mandingo language, of which he had hastily acquired a superficial knowledge, excited suspicions of danger; and gave him intimation of a conspiracy which the negro mistresses of the traders, who feared that the Major's expedition portended the ruin of their commerce, had formed against his life. Afraid, therefore, of travelling by the customary route, he availed himself of the opportunity which the dry season

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Houghton son and the tide of ebb afforded of swimming his horse and his asses across the stream; and having by those means avoided the parties who were sent for his destruction, he proceeded with much difficulty on the southern side of the river, to that district of Cantor which is opposite to the kingdom of Woollî. There he repassed the Gambia, and set a messenger to inform the king of his arrival, and to request a guard for his protection.

An escort, commanded by the king's son, was immediately dispatched; and the Major, whose intended present had been announced, was kindly received, and hospitably entertained at Medina.

The town is situated at the distance of about 900 miles by water from the entrance of the Gambia; and the country adjacent abounds in corn and cattle, and, generally speaking, in all things that are requisite for the support, or essential to the comfort of life. Two different sects of religion distinguish rather than divide the people; the one is composed of the professors of the Mahomedan faith, who are called Bushreens; the other, and, it is said, the more numerous, consists of those who, denying the mission of the prophet, avow themselves deists, and from their custom of drinking with freedom the liquors of which he prohibited the use, are denominated Sonikees or drinking men.

In a letter from Major Houghton to his wife, which a seaman preserved from the wreck of a vessel in which the dispatches to the society were lost, the Major indulged the reflections that naturally arose from his past and present situations. A bilious fever had attacked him soon after his arrival in the Gambia; but his health was now unimpaired—a conspiracy had assailed his life; but the danger was passed—the journey from Junkiconda had exposed him to innumerable hardships; but he was now in possession of every gratification which the kindness of the king or the hospitality of the people could enable him to enjoy. Delighted with the healthiness of the country, the abundance of the game, the security with which he made his excursions on horseback, and, above all, with the advantages that would attend the erection of a fort on the salubrious and beautiful hill of Fatetenda, where the English once had a factory, he expresses his earnest hope that his wife will hereafter accompany him to a place in which an income of ten pounds a-year will support them in affluence; and that she will participate with him in the pleasure of rapidly acquiring that vast wealth which he imagines its commerce will afford.

While, in this manner, he indulged the dream of future prosperity, and with still more ample satisfaction contemplated the eclat of the discoveries for which he was preparing, but in the pursuit of which he was retarded by the absence of the native merchant, for whose company he had engaged, he found himself suddenly involved in unexpected and irresistible misfortune. A fire, the progress of which was accelerated by the bamboo roofs of the buildings, consumed with such rapidity the house in which he lived, and with it the greatest part of Medina, that several of the articles of merchandize, to which he trusted for the expences of his journey, were destroyed; and to add to his affliction, his faithless interpreter, who had made an ineffectual attempt on his goods, disappeared with his horse and three of his asses; a trade gun which he had purchased on the river soon afterwards burst in his hands,

and wounded him in the face and arm: and though the hospitable kindness of the people of the neighbouring town of Barraconda, who cheerfully opened their houses to more than a thousand families, whose tenements the flames had consumed, was anxiously exerted for his relief; yet the loss of his goods, and the consequent diminution of his travelling fund, were evils which no kindness could remove.

It was in this situation that, wearied with the fruitless hope of the return of the native trader, with whom he had contracted for his journey, he resolved to avail himself of the company of another slave merchant, who was lately arrived from the south, and was now on his way to his farm on the frontier of the kingdom of Bambouk. Accordingly, on the evening of the 8th of May, he proceeded by moon light and on foot, with his two asses, which the servants of the slave merchant offered to drive with their own, and which carried the wreck of his fortune; and journeying by a north-east course, arrived on the fifth day at the uninhabited frontier which separates the kingdoms of Woollî and Bondou.

He had now passed the former limit of European discovery; and while he remarked with pleasure the numerous and extensive population of this unvisited country, he observed, that the long black hair and copper complexion of the inhabitants announced their Arab original. They are a branch of that numerous tribe which, under the appellation of Foolies, have overspread a considerable part of Senegambia; and their religious distinctions are similar to those which prevail in the kingdom of Woollî.

A journey of 150 miles, which was often interrupted by the engagements of his companion who traded in every town, conducted him to the banks of the Falemé, the south-western boundary of the kingdom of Bambouk. Its stream was exhausted by the advanced state of the dry season, and its bed exhibited an appearance of slate intermixed with gravel.

Bambouk is inhabited by a nation, whose woolly hair and sable complexions bespeak them of the negro race, but whose character seems to be varied in proportion as the country rises from the plains of its western division to the highlands of the east. Distinguished into sects, like the people of Woollî and Bondou, by the different tenets of Mahomedans and Deists, they are equally at peace with each other, and mutually tolerate the respective opinions they condemn.

Agriculture and pasturage, as in the negro states on the coast of the Atlantic, are their chief occupations; but the progress which they have made in the manufacturing arts, is such as enables them to smelt their iron ore, and to furnish the several instruments of husbandry and war. Cloth of cotton, on the other hand, which in this part of Africa seems to be the universal wear, they appear to weave by a difficult and laborious process; and to these two circumstances it is probably owing, that with them the measure of value is not, as on the coast, a bar of iron, but a piece of cloth.

The common vegetable food of the inhabitants appears to consist of rice; their animal, of beef or mutton. A liquor, prepared from fermented honey, supplies the want of wine, and furnishes the means of those festive entertainments that constitute the luxury of the court of Bambouk.

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On the Major's arrival at the banks of the river Falemé, he found that the war which had lately subsisted between the kings of Bondou and Bambouk was terminated by the cession to the former of the conquests he had made in the low land part of the dominions of the latter; and that the king of Bondou had taken up his residence in the territory which he had thus obtained.

The Major hastened to pay his respects to the victorious prince, and to offer a similar present to that which the kings of Barra and Woilli had cheerfully accepted; but to his great disappointment an ungracious reception, a fullen permission to leave the present, and a stern command to repair to the frontier town from which he came, were followed by an intimation that he should hear again from the king. Accordingly, on the next day, the king's son, accompanied by an armed attendance, entered the house in which the Major had taken up his temporary dwelling, and demanded a sight of all the articles he had brought. From these the prince selected whatever commodities were best calculated to gratify his avarice, or please his eye; and, to the Major's great disappointment, took from him the blue coat in which he hoped to make his appearance on the day of his introduction to the Sultan of Tombuctoo. Happily, however, a variety of articles were successfully concealed, and others of inferior value were not considered as sufficiently attractive.

The Major now waited with impatience for the performance of the promise which the slave merchant, with whom he had travelled from the Gambia, had made of proceeding with him to Tombuctoo; but as the merchant was obliged to spend a few days at his rice farm on the banks of the Falemé, the Major accepted an invitation to the hospitality of his roof. There he observed, with extreme regret, that the apprehension of a scarcity of grain had alarmed his friend; and that, dreading the consequences of leaving his family in so perilous a season to the chances of the market, he had determined on collecting, before his departure, a sufficient supply for their support. This argument for delay was too forcible to be opposed; and therefore the Major resolved to employ the interval in visiting the king of Bambouk, who resided in the town of Ferbanna, on the eastern side of the Serra Coles, or river of Gold. Unfortunately, however, by a mistake of his guide, he lost his way in one of the vast woods of the country; and as the rainy season, which commenced with the new moon on the 4th of July, and was introduced with a westerly wind, was now set in, the ground on which he passed the night was deluged with rain, while all the sky exhibited that continued blaze of lightning, which in those latitudes often accompanies the tornado. Distressed by the fever, which began to assail him, the Major continued his route at the break of day, and waded with difficulty through the river Serra Coles, which was swelled by the floods, and on the banks of which the alligators were basking in the temporary sun-shine.

Scarcely had he reached Ferbanna when his fever rose to a height that rendered him delirious; but the strength of his constitution, and the kindness of the negro family to which his guide had conducted him, surmounted the dangerous disease; and in the friendly reception which was given him by the king of Bambouk

he soon forgot the hardships of his journey. The king informed him, that the losses he had lately sustained in the contest with the armies of Bondou, arose from his having exhausted his ammunition; for, as the French traders, who formerly supplied his troops, had abandoned the fort of St Joseph, and, either from the dryness of the last season, or from other causes, had deserted the navigation of the upper part of the Senegal, he had no means of replenishing his stores; whereas his enemy, the king of Bondou, continued to receive from the British, through the channel of his agents on the Gambia, a constant and adequate supply.

Major Houghton availed himself of the opportunity which this conversation afforded, to suggest to the king the advantage of encouraging the British to open a trade by the way of his dominions to the populous cities on the banks of the Niger.

Such was the state of the negotiation, when all business was suspended by the arrival of the annual presents of Mead, which the people of Bambouk, at that season of the year, are accustomed to send to their king; and which are always followed by an intemperate festival of several successive days.

In the interim, the Major received, and gladly accepted, the proposal of an old and respectable merchant of Bambouk; who offered to conduct him on horseback to Tombuctoo, and to attend him back to the Gambia. A premium of L. 125, to be paid on the Major's return to the British factory at Junkiconda, was fixed by agreement as the merchant's future reward. It was further determined that the Major should be furnished with a horse in exchange for his two asses; and should convert into gold dust, as the most portable fund, the scanty remains of the goods he had brought from Great Britain.

This plan was much approved by the king, to whom the merchant was personally known; and who gave to the Major at parting, as a mark of his esteem, and a pledge of his future friendship, a present of a purse of gold. With an account of these preparations the Major closed his last dispatch, of the 24th July 1791; and the African association entertained for some time sanguine hopes of his reaching Tombuctoo. Alas! these hopes were blasted. Mr Park, who succeeded him in the arduous task of exploring that savage country, learned, that having reached JARRA (See that article in this *Supplement*), he there met with some Moors who were travelling to Tilheet (a place by the salt pits in the Great Desert, ten days journey to the northward) to purchase salt; and that the Major, at the expence of some tobacco and a musket, engaged them to convey him hither. It is impossible (says Mr Park) to form any other opinion on this determination, than that the Moors intentionally deceived him with a view to rob, and leave him in the Desert. At the end of two days he suspected their treachery, and insisted on returning to Jarra. Finding him persist in this determination, the Moors robbed him of every thing which he possessed, and went off with their camels. Being thus deserted, he returned to a watering place, in possession of the Moors, called Farra; and being by these unfeeling wretches refused food, which he had not tasted for some days, he sunk at last under his misfortunes. Whether he actually died of hunger, or was murdered outright by the savage Mahometans, Mr Park could not learn; but

Houffa. but he was shewn at a distance the spot in the woods to which his body was dragged, and where it was left a prey to corruption.

Thus perished, in the prime of life, Major Houghton, a man whose travels enlarged the limits of European discovery, and whose accounts of the places which he visited were strongly confirmed by the intelligence which the British consul at Tunis collected from the Barbary merchants.

HOUSSA, the capital of an African empire, on the banks of the Niger, is a city which has excited much curiosity among men of science, since it was first mentioned to a committee of the African Association about the year 1790. The person from whom they received their information was an Arab, of the name of Shabeni; who said that the population of Houffa, where he had resided two years, was equalled only (so far as his knowledge extended) by that of London and Cairo: and, in his rude unlettered way, he described the government as monarchical, yet not unlimited; its justice as severe, but directed by written laws; and the rights of landed property as guarded by the institutions of certain hereditary officers, whose functions appear to be similar to those of the Canongoes of Hindostan (see CANONGOES in this *Suppl.*); and whose important and complicated duties imply an unusual degree of civilization and refinement. For the probity of the merchants of Houffa, the Arab expressed the highest respect; but remarked, with indignation, that the women were admitted to society, and that the honour of the husband was often insecure. Of their written alphabet, he knew no more than that it is perfectly different from the Arabic and the Hebrew characters; but he represented the art of writing as common in Houffa. And when he described the manner in which their pottery is made, he gave, unknowingly to himself, a representation of the ancient Grecian wheel. In passing to Houffa from Tombuctoo, in which last city he had resided seven years, he found the banks of the Niger more numerously peopled than those of the Nile, from Alexandria to Cairo; and his mind was obviously impressed with higher ideas of the wealth and grandeur of the empire of Houffa, than of those of any kingdom which he had seen, England alone excepted.

The existence of the city of Houffa, and of the empire thus described by Shabeni, was strongly confirmed by letters which the committee received from his Majesty's consuls at Tunis and Morocco; and it has been put beyond all possibility of doubt by Mr Park, who received from various persons such concurring accounts of it, as could not be the offspring of deliberate falsehood. From a well-informed thereeff, who had visited Houffa, and lived some years at Tombuctoo, he learned that the former of these cities was the largest that the thereeff had ever seen; and by comparing this man's account of its population with that of various other cities, of which Mr Park had seen one or two, we can hardly estimate the inhabitants of Houffa at a less number than 100,000. Many merchants, with whom our traveller conversed, represented Houffa as larger, and more populous, than Tombuctoo, and the trade, police, and government, as nearly the same in both. In that case, the king of Houffa and chief officers of state must be Moors, and zealots for the Mahometan religion; but they cannot be so intolerant as the sovereign of Tom-

buctoo and his ministers; for in Houffa, Mr Park was told that the Negroes are in greater proportion to the Moors than in Tombuctoo, and that they have likewise some share in the government. According to accounts derived from Barbary merchants, the people of Houffa have the art of tempering their iron with more than European skill; and their files, in particular, are much superior to those of Great Britain and France. The consuls at Tunis and Morocco assured the committee of the African Association, that at both these courts the eunuchs of the seraglio are brought from Houffa.

To those who may still entertain doubts of so much refinement being to be found in the interior parts of a country, considered as peculiarly savage, we shall only observe, in the words of the committee of association, that it is by no means "impossible that the Carthaginians, who do not appear to have perished with their cities, may have retired to the southern parts of Africa; and though lost to the Desert, may have carried with them to the new regions which they occupy some portion of those arts and sciences, and of that commercial knowledge, for which the inhabitants of Carthage were once so eminently famed. In Major Rennel's last map of North Africa, Houffa is placed in 16° and about 20' N. Lat. and 4° 30' E. Long.

HOZOUANAS, are a wandering people, who inhabit that part of Africa, which, in a direction from east to west, extends from Cassaria to the country of the Greater Nimiquas (See NIMIQUEAS in this *Suppl.*) According to the map prefixed to Vaillant's new travels, the district occupied by the Houzouanas lies between 16° and 29° east longitude. Of its breadth from south to north we are ignorant, but it begins at the 23d parallel, and stretches northward probably a great way.

M. Vaillant is inclined to believe, that the Houzouanas are the original stem of the various nations, inhabiting at present the southern part of Africa, and that from them all the tribes of the eastern and western Hottentots are descended. The people themselves know nothing of their origin; but to the questions that are put to them on the subject, they always reply, that they inhabit the country which was inhabited by their ancestors. At the Cape M. Vaillant received the following account of them, which, though he does not warrant its authenticity, has much the appearance of being authentic.

When the Europeans first established themselves at the Cape, the Houzouanas inhabited the country of Camdebo, the snowy mountains, and the district that separates these mountains from Caffaria. Become neighbours to the colony, in consequence of its extending itself towards them, they at first lived on peaceable terms with the planters; and, as they displayed more intelligence and greater activity than the Hottentots, they were even employed in preference to assist in cultivating the land and in forming the settlement. This good understanding and harmony were, however, soon interrupted by that multitude of lawless banditti sent from Holland to people the country.

Those worthless profligates wished to enjoy the fruits of the land without the trouble of tilling it. Educated, besides, with all the prejudices of the whites, they imagined that men of a different colour were born only

Houffa,
Houzou-
anas.

Houzou-
anae. to be their slaves. They accordingly subjected them to bondage, condemned them to the most laborious services, and repaid those services with harsh and severe treatment. The Houzouanas, incensed at such arbitrary and tyrannical conduct, refused any longer to work for them, and retired to the defiles of their mountains. The planters took up arms and pursued them; they massacred them without pity, and seized on their cattle and their country. Those who escaped their atrocities betook themselves to flight, and removed to the land which they now occupy; but, on quitting their former possessions, they swore, in their own name and that of their posterity, to exterminate those European monsters, to be revenged against whom they had so many incitements. And thus, if tradition be true, was a peaceful and industrious nation rendered warlike, vindictive, and ferocious.

This hatred has been perpetuated from generation to generation, though the Houzouanas of the present day are ignorant of the original cause of it. Bred up with an invincible aversion to the planters, they know only that they are animated to plunder and destroy them; but it is only by a vague sentiment of detestation, with the source of which they are unacquainted; and which, though it renders them cruel towards the planters, does not prevent them from being good, kind, and humane, towards each other.

The Houzouanas, being known only by their incursions and plundering, are in the colonies often confounded with the Boshmen, and distinguished by the same appellation. Sometimes, however, from their tawny colour, they are called Chinese Hottentots; and, by means of this double denomination, ill-informed travellers may easily be led into an error, of which the consequence must be, that their narratives will be replete with absurdity and falsehoods.

Their real name, and the only one which they give themselves, is that of Houzouana; and they have nothing in common with the Boshmen, who are not a distinct people, but a mere collection of fugitives and free-booters. The Houzouanas form no alliances but among themselves. Being almost always at war with the surrounding nations, they never mix with them; and, if they consent at any time to admit a stranger into their hordes, it is only after a long acquaintance, a sort of apprenticeship, during which he has given proofs of his fidelity, and established his courage. Such indeed are their courage and predatory habits, that they are the dread of all the surrounding tribes; and the Hottentots who accompanied M. Vaillant trembled at the very thought of entering the Houzouana territories. Nay, after they had lived many days among them, and had experienced their fidelity, they continued under the daily apprehension of being massacred by them. Yet one of their own countrymen, who had lived long among the Houzouanas, gave such a character of that people as should have banished those idle fears.

“The Houzouanas (said he), are by no means what you suppose them to be, murderers by profession. If they sometimes shed blood, it is not from a thirst of carnage, but to make just reprisals that they take up arms. Attacked and persecuted by surrounding nations, they have found themselves reduced to the ne-

cessity of flying to inaccessible places among the barren mountains, where no other people could exist.

“If they find antelopes and damans to kill; if the nymphs of ants are abundant; or if their good fortune brings them plenty of locusts—they remain within the precincts of their rocks; but if the provisions necessary to subsistence fail, the nations in their neighbourhood must suffer. From the summits of their mountains, they survey at a distance the countries around; and if they observe cattle, they make an incursion to carry them off, or slaughter them upon the spot, according to circumstances; but though they rob, they never kill, except to defend their lives, or by way of retaliation to revenge an ancient injury.

“It happens sometimes, however, that after very fatiguing expeditions they return without booty; either because the objects of their attack have disappeared, or because they have been repulsed and beaten. In such cases, the women, exasperated by hunger and the lamentation of their children crying for food, become almost furious with passion. Reproaches, insult, and threats, are employed; they wish to separate from such dastardly men, to quit husbands destitute of courage, and to seek others who will be more anxious to procure provision for them and their children. In short, having exhausted whatever rage and despair could suggest, they pull off their small apron of modesty, and beat their husbands about the head with it till their arms are weary of the exercise.

“Of all the affronts which they can offer, this is the most insulting. Unable to withstand it, the men in their turn become furious. They put on their war-cap, a sort of helmet made with the skin that covers the neck of the hyæna, the long hair of which forms a crest that floats over the head, and setting out like madmen, never return till they have succeeded in carrying off some cattle.

“When they come back, their wives go to meet them, and extol their courage amidst the fondest caresses. In a word, nothing is then thought of but mirth and jollity; and, till similar scenes are recalled by similar wants, past evils are forgotten.”

Such was the character given of this formidable people to M. Vaillant at his first interview with them; and during the long excursions which he made in their company, they did not belie it in a single instance. In many respects they appeared to resemble the Arabs, who, being also wanderers, and like them brave and addicted to rapine, adhere with unalterable fidelity to their engagements, and defend, even to the last drop of their blood, the traveller who civilly purchases their services, and puts himself under their protection. In our author's opinion, if it be at all practicable to traverse from south to north the whole of Africa, it could only be under the conduct of the Houzouanas; and he really thinks that fifty men of their temperate, brave, and indefatigable nation, would be sufficient to protect an enterprising European through that long and hazardous journey.

Yet these people, so superior both in body and mind to the other natives of South Africa, are but of low stature; and a person five feet four inches in height is accounted among them very tall; but in their little bodies, perfectly well proportioned, are united, with sur-
prising

Houzo-
anas. prising strength and agility, a certain air of assurance, boldness, and haughtiness, which awes the beholder, and with which our author was greatly pleased. Of all the savage races, he saw none that appeared to be endowed with so active a mind, and so hardy a constitution.

Their head, though it exhibits the principal characteristics of that of the Hottentot, is, however, rounder towards the chin. They are also not so black in complexion; but have the lead colour of the Malays, distinguished at the Cape by the name of *bouguinée*. Their hair, more woolly, is so short, that he imagined at first their heads to have been shaved. The nose too is still flatter than that of the Hottentots; or, rather, they seem altogether destitute of a nose; what they have consisting only of two broad nostrils which project at most but five or six lines. From this confirmation of the nose, a Houzouana, when seen in profile, is the reverse of handsome, and considerably resembles an ape. When beheld in front, he presents, on the first view, an extraordinary appearance, as half the face seems to be forehead. The features, however, are so expressive, and the eyes so large and lively, that, notwithstanding this singularity of look, the countenance is tolerably agreeable.

As the heat of the climate in which he lives renders clothing unnecessary, he continues during the whole year almost entirely naked, having no other covering than a very small jackal skin fastened round his loins by two thongs, the extremities of which hang down to his knees. Hardened by this constant habit of nakedness, he becomes so insensible to the variations of the atmosphere, that when he removes from the burning sands of the level country to the snow and hoar-frost of his mountains, he seems indifferent to and not even to feel the cold.

His hut in nowise resembles that of the Hottentot. It appears as if cut vertically through the middle; so that the hut of a Hottentot would make two of those of the Houzouanas. During their emigrations, they leave them standing, in order that, if any other horde of the same nation pass that way, they may make use of them. When on a journey, they have nothing to repose on but a mat suspended from two sticks, and placed in an inclined position. They often even sleep on the bare ground. A projecting rock is then sufficient to shelter them; for every thing is suited to a people whose constitutions are proof against the severest fatigue. If, however, they stop anywhere to sojourn for a while, and find materials proper for constructing huts, they then form a kraal; but they abandon it on their departure, as is the case with all the huts which they erect.

This custom of labouring for others of their tribe announces a social character and a benevolent disposition. They are indeed not only affectionate husbands and good fathers, but excellent companions. When they inhabit a kraal, there is no such thing among them as private property; whatever they possess is in common. If two hordes of the same nation meet, the reception is on both sides friendly; they afford each other mutual protection, and confer reciprocal obligations. In short, they treat one another as brethren, though perhaps they are perfect strangers, and have never seen each other before.

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Active and nimble by nature, the Houzouanas consider it as amusement to climb mountains, and the most elevated peaks; and they conducted M. Vaillant, his servants and cattle, over precipices, and through defiles, which he and his Hottentots would have deemed absolutely impassable. The only arms of this people are bows and arrows, in the use of which they are very expert. The arrows, which are uncommonly short, are carried on the shoulder in a quiver, about 18 inches in length, and four in diameter, made of the bark of the aloe, and covered with the skin of a large species of lizard, which these wanderers find in all their rivers, particularly on the banks of Orange and Fish River.

Nocturnal fires are a peculiar language understood and employed by almost all savage nations. None, however, have carried this art so far as the Houzouanas, because none have so much need of understanding and bringing it to perfection. If it be necessary to announce a defeat or a victory, an arrival or departure, a successful plundering expedition, or the want of assistance, in a word, any intelligence whatever, they are able, either by the number of their fires or the manner in which they arrange them, to make it known in an instant. They are even so sagacious as to vary their fires from time to time, lest their enemies should become acquainted with their signals, and treacherously employ them in their turn to surprize them.

Our author says, that he is unacquainted with the principles of these signals, invented with so much ingenuity. He did not request information; because he very rationally inferred that his request would not have been granted; but he observed, that three fires kindled at the distance of twenty paces from each other, so as to form an equilateral triangle, were the signal for rallying.

Among the physical qualities which, in M. Vaillant's opinion, prove that the Houzouanas are a distinct nation, he mentions the enormous natural rump of the women, as a deformity which distinguishes them from every other people, savage or polished, which he had ever known. "I have several times (says he) had occasion to remark, that, among the female Hottentots in general, as they advance in age, the inferior part of the back swells out, and acquires a size which it greatly exceeds the proportion it bore in infancy with the other parts of the body. The Houzouana women, having in their figure some resemblance to the Hottentots, and appearing therefore to be of the same race, one might be induced to believe that their projection behind is only the Hottentot rump more swelled and extended. I observed, however, that among the former this singularity was an excrescence of slow growth, and in some measure an infirmity of old age; whereas among the latter it is a natural deformity, an original characteristic of their race. The Houzouana mothers wear on their reins, like our miners, a skin which covers this protuberance of the posteriors; but which, being thin and pliable, yields to the quivering of the flesh, and becomes agitated in the same manner. When on a journey, or when they have children too young to follow them, they place them upon their rump. I saw one of these women run in this manner with a child, about three years of age, that stood erect on its feet at her back, like a footboy behind a carriage."

If one half of what our traveller says of the activity

Hungary-
water.

and enterprising spirit of this singular people be true, might not the African Association lend a second Houghton, or second Park, to make discoveries in that unexplored country, under the protection of the Houzouanas? We do not indeed think that it would be possible to traverse the whole extent of Africa from south to north, but Vaillant penetrated farther in that direction than any one had done before him; and it appears that with his intrepid Houzouanas he might have penetrated much farther.

Hist. of In-
ventions.

HUNGARY-WATER, is spirit of wine distilled upon rosemary, and which therefore contains its oily and strong-scented essence (see PHARMACY, n^o 365. *Encycl.*) To be really good, says Professor Beckmann, the spirit of wine ought to be very strong, and the rosemary fresh; and if that be the case, the leaves are as proper as the flowers, which, according to the prescription of some, should only be taken. It is likewise necessary that the spirit of wine be distilled several times upon the rosemary; but that process is too troublesome and expensive to admit of this water being disposed of at the low price it is usually sold for; and it is certain that the greater part of it is nothing else than common brandy united with the essence of rosemary in the simplest manner. In general, it is only mixed with a few drops of the oil. For a long time past, this article has been brought to us principally from France, where it is prepared, particularly at Beaucaire, Montpellier, and other places in Languedoc, in which that plant grows in great abundance.

The name *Hungary water* seems to signify, that this water, so celebrated for its medicinal virtues, is an Hungarian invention; and we read in many books, that the receipt for preparing it was given to a queen of Hungary by a hermit; or, as others say, by an angel, who appeared to her in a garden, all entrance to which was shut, in the form of a hermit or a youth. Some call the queen St Isabella; but those who pretend to be best acquainted with the circumstance affirm, that Elizabeth, wife of Charles Robert king of Hungary, and daughter of Uladislaus II. king of Poland, who died in 1380 or 1381, was the inventress. By often washing with this spirit of rosemary, when in the 70th year of her age, she was cured, as we are told, of the gout and an universal lameness; so that she not only lived to pass 80, but became so lively and beautiful, that she was courted

by the king of Poland, who was then a widower, and who wished to make her his second wife.

Hunter.

The Professor justly considers this story as a ridiculous fable (A). "It appears to me (says he) most probable, that the French name *l'eau de la reine d'Hongrie*, was chosen by those who, in latter times, prepared spirit of rosemary for sale, in order to give greater consequence and credit to their commodity; as various medicines, some years ago, were extolled in the gazettes under the title of Pompadour, though the celebrated lady, from whose name they derived their importance, certainly neither ever saw them nor used them."

HUNTER (John), the celebrated surgeon, was the youngest child of John Hunter of Kilbride, in the county of Lanark. He was born on the 14th of July 1728, at Long Calderwood, a small estate belonging to the family; and losing his father when he was about ten years of age, he was perhaps too much indulged by his mother. One consequence of this was, that at the grammar-school he made no progress in learning; and he may be said to have been almost totally illiterate when, in September 1748, he arrived in London. His brother, Dr William Hunter, of whom an account is given in the *Encyclopaedia*, was then the most celebrated teacher of anatomy, and John had expressed a desire to assist him in his researches. The Doctor, who was very desirous to serve him, and anxious to form some opinion of his talents for anatomy, gave him an arm to dissect for the muscles, with the necessary directions how it was to be done; and he found the performance such as greatly exceeded his expectation.

His first essay in anatomy having thus gained him some credit, Mr Hunter was now employed in a dissection of a more difficult nature; this was an arm in which all the arteries were injected, and these, as well as the muscles, were to be exposed and preserved. The manner in which this was performed, gave Dr Hunter so much satisfaction, that he did not scruple to say that his brother would become a good anatomist, and that he should not want for employment. From this period we may consider Mr Hunter as having seriously engaged in anatomy; and under the instructions of Dr Hunter, and his assistant Mr Symonds, he had every opportunity of improvement, as all the dissections at this time carried on in London were confined to that school.

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(A) It was first published to the world in 1659 in a posthumous work of John Prevot, who says, that in the beginning of a very old breviary, he saw a remedy for the gout, written by the queen's own hand, in the following words:

"I Elizabeth, queen of Hungary, being very infirm and much troubled with the gout in the 72d year of my age, used for a year this receipt, given to me by an ancient hermit, whom I never saw before nor since; and was not only cured, but recovered my strength, and appeared to all so remarkably beautiful, that the king of Poland, asked me in marriage, he being a widower and I a widow. I, however, refused him for the love of my Lord Jesus Christ, from one of whose angels, I believe, I received the remedy. The receipt is as follows:

"B. Take of aqua vitæ, four times distilled, three parts, and of the tops and flowers of rosemary two parts: put these together in a close vessel, let them stand in a gentle heat 50 hours, and then distil them. Take one dram of this in the morning once every week, either in your food or drink, and let your face and the diseased limb be washed with it every morning.

"It renovates the strength, brightens the spirits, purifies the marrow and nerves, restores and preserves the sight, and prolongs life." Thus far from the Breviary. Then follows a confirmation which Prevot gives from his own experience.

Hunter. In the summer 1749, Mr Cheselden, at the request of Dr Hunter, permitted him to attend at Chelsea Hospital; and he there learned the first rudiments of surgery.

The following winter he was so far advanced in the knowledge of human anatomy, as to instruct the pupils in dissection, to whom Dr Hunter had very little time to pay attention. This office, therefore, fell almost entirely upon him, and was his constant employment during the winter season.

In the summer months of 1750, Mr Hunter attended the hospital at Chelsea; in 1751, he became a pupil at St Bartholomew's, and in the winter was present at operations occasionally, whenever any thing extraordinary occurred. The following summer he went to Scotland; and in 1753 entered, it is difficult to conceive for what reason, as a gentleman commoner at St Mary-hall, Oxford. In 1754 he became a surgeon's pupil at St George's hospital, where he continued during the summer months; and in 1756 was appointed house-surgeon.

In the winter 1755, Dr Hunter admitted him to a partnership in his lectures, and a certain portion of the course was allotted to him; besides which, he gave lectures when the Doctor was called away to attend his patients. Making anatomical preparations was at this time a new art, and very little known; every preparation, therefore, that was skilfully made, became an object of admiration; many were wanting for the use of the lectures; and the Doctor being himself an enthusiast for the art, left no means untried to infuse into his brother a love for his favourite pursuits. How well he succeeded, the collection afterwards made by Mr Hunter will sufficiently evince.

Anatomy seems to have been a pursuit for which Mr Hunter's mind was peculiarly fitted, and he applied to it with an ardour and perseverance of which there is hardly an example. His labours were so useful to his brother's collection, and so gratifying to his disposition, that although in many other respects they did not agree, this simple tie kept them together for many years.

Mr Hunter worked for ten years on human anatomy; during which period he made himself master of what was already known, as well as made some addition to that knowledge. He traced the ramifications of the olfactory nerves upon the membranes of the nose, and discovered the course of some of the branches of the fifth pair of nerves. In the gravid uterus, he traced the arteries of the uterus to their termination in the placenta. He was also the first who discovered the existence of the lymphatic vessels in birds.

Many parts of the human body being so complex, that their structure could not be understood, nor their uses ascertained, Mr Hunter was led to examine similar parts in other animals, in which the structure was more simple, and more within the reach of investigation; this carried him into a wide field, and laid the foundation of his collection in comparative anatomy.

In this new line of pursuit, this active inquirer began with the more common animals, and preserved such parts as appeared by their analogy, or in some other way, to elucidate the human economy. It was not his intention to make dissections of particular animals, but to institute an inquiry into the various organizations

by which the functions of life are performed, that he might thereby acquire some knowledge of general principles. Hunter.

So eagerly did Mr Hunter attach himself to comparative anatomy, that he sought by every means in his power the opportunities of prosecuting it with advantage. He applied to the keeper of wild beasts in the Tower for the bodies of those which died there; and he made similar applications to the men who showed wild beasts. He purchased all rare animals which came in his way; and these, with such others as were presented to him by his friends, he entrusted to the showmen to keep till they died, the better to encourage them to assist him in his labours.

His health was so much impaired by excessive attention to his pursuits, that in the year 1760 he was advised to go abroad, having complaints in his breast which threatened to be consumptive. In October of that year, Mr Adair, inspector-general of hospitals, appointed him a surgeon on the staff; and in the following spring he went with the army to Bellisle, leaving Mr Hewson to assist his brother during his absence.

Mr Hunter served, while the war continued, as senior surgeon on the staff, both in Bellisle and Portugal, till the year 1763; and in that period acquired his knowledge of gun-shot wounds. On his return to England he settled in London; where, not finding the emoluments from his half-pay and private practice sufficient to support him, he taught practical anatomy and operative surgery for several winters. He returned also, with unabated ardour, to comparative anatomy; and as his experiments could not be carried on in a large town, he purchased for that purpose, about two miles from London, a piece of ground near Brompton, at a place called Earl's Court, on which he built a house. In the course of his inquiries, this excellent anatomist ascertained the changes which animal and vegetable substances undergo in the stomach when acted on by the gastric juice; he discovered, by means of feeding young animals with madder (which tinges growing bones red), the mode in which a bone retains its shape during its growth; and explained the process of exfoliation, by which a dead piece of bone is separated from the living.

His fondness for animals made him keep several of different kinds in his house, which, by attention, he rendered familiar with him, and amused himself by observing their peculiar habits and instincts; but this familiarity was attended with considerable risk, and sometimes led him into situations of danger, of which the following is a remarkable instance:

Two leopards, which were kept chained in an out-house, had broken from their confinement, and got into the yard among some dogs, which they immediately attacked; the howling this produced alarmed the whole neighbourhood; Mr Hunter ran into the yard to see what was the matter, and found one of them getting up the wall to make his escape, the other surrounded by the dogs; he immediately laid hold of them both, and carried them back to their den; but as soon as they were secured, and he had time to reflect upon the risk of his own situation, he was so much agitated, that he was in danger of fainting.

On the fifth of February 1767, he was chosen a fellow

Hunter. low of the Royal Society. His desire for improvement in those branches of knowledge which might assist in his researches, led him at this time to propose to Dr George Fordyce and Mr Cumming, an eminent mechanic, that they should adjourn from the meetings of the Royal Society to some coffee-house, and discuss such subjects as were connected with science. This plan was no sooner established, than they found their numbers increased; they were joined by Sir Joseph Banks, Dr Solander, Dr Maskelyne, Sir George Shuckburgh, Sir Harry Englefield, Sir Charles Blagden, Dr Noothe, Mr Ramsden, Mr Watt of Birmingham, and many others. At these meetings discoveries and improvements in different branches of philosophy were the objects of their consideration; and the works of the members were read over and criticised before they were given to the public. It was in this year that, by an exertion in dancing, after the muscles of the leg were fatigued, he broke his tendo achillis. This accident, and the confinement in consequence of it, led him to pay attention to the subject of broken tendons, and to make a series of experiments to ascertain the mode of their union.

In the year 1768 Mr Hunter became a member of the corporation of surgeons; and in the year following, through his brother's interest, he was elected one of the surgeons of St George's hospital. In May 1771, his Treatise on the Natural History of the Teeth was published; and in July of the same year he married Miss Home, the eldest daughter of Mr Home, surgeon to Burgoyne's regiment of light horse. The expence of his pursuits had been so great, that it was not till several years after his first engagement with this lady that his affairs could be sufficiently arranged to admit of his marrying.

Though after his marriage his private practice and professional character advanced rapidly, and though his family began to increase, he still devoted much of his time to the forming of his collection, which, as it daily became larger, was also attended with greater expence. The whole suit of the best rooms in his house were occupied by his preparations; and he dedicated his mornings, from sunrise to eight o'clock (the hour for breakfast), entirely to his pursuits. To these he added such parts of the day as were not engaged in attending his patients.

The knowledge he derived from his favourite studies he constantly applied to the improvement of the art of surgery, and omitted no opportunity of examining morbid bodies; from which he made a collection of facts which are invaluable, as they tend to explain the real causes of symptoms, which, during life, could not be exactly ascertained, the judgment of the practitioner being too frequently misled by theoretical opinions, and delusive sensations of the patients.

In the practice of surgery, where cases occurred in which the operations proved inadequate to their intention, he always investigated, with uncommon care, the causes of that want of success; and in this way detected many fallacies, as well as made some important discoveries, in the healing art. He detected the cause of failure, common to all the operations in use for the radical cure of the hydrocele, and was enabled to propose a mode of operating, in which that event can with certainty be avoided. He ascertained; by experiments

and observations, that exposure to atmospherical air simply, can neither produce nor increase inflammation. He discovered in the blood so many phenomena connected with life, and not to be referred to any other cause, that he considered it as alive in its fluid state. He improved the operation for the fistula lachrymalis, by removing a circular portion of the os unguis instead of breaking it down with the point of a trocar. He also discovered that the gastric juice had a power when the stomach was dead of dissolving it; and gave to the Royal Society a paper on this subject, which is published in the Philosophical Transactions.

In the winter 1773, he formed a plan of giving a course of lectures on the theory and principles of surgery, with a view of laying before the public his own opinions upon that subject. For two winters he read his lectures *gratis* to the pupils of St George's Hospital; and in 1775, gave a course for money upon the same terms as the other teachers in the different branches of medicine and surgery. But giving lectures was always particularly unpleasant to him; so that the desire of submitting his opinions to the world, and learning their general estimation, were scarcely sufficient to overcome his natural dislike to speaking in public. He never gave the first lecture of his course without taking 30 drops of laudanum to take off the effects of his uneasiness.

Comparative anatomy may be considered as the pursuit in which Mr Hunter was constantly employed. No opportunity escaped him. In the year 1773, at the request of his friend Mr Walsh, he dissected the torpedo, and laid before the Royal Society an account of its electrical organs. A young elephant, which had been presented to the Queen by Sir Robert Barker, died, and the body was given to Dr Hunter, which afforded Mr Hunter an opportunity of examining the structure of that animal by assisting his brother in the dissection; since that time two other elephants died in the Queen's menagerie, both of which came under Mr Hunter's examination. In 1774, he published in the Philosophical Transactions an account of certain receptacles of air in birds, which communicate with the lungs, and are lodged both among the fleshy parts and hollow bones of these animals; and a paper on the Gizzard-trout.

In 1775, several animals of that species, called the *gymnotus electricus of Surinam*, were brought alive to this country, and by their electrical properties excited very much the public attention. Mr Walsh, desirous of pursuing his investigations of animal electricity, made a number of experiments on the living animals; and to give his friend Mr Hunter an opportunity of examining them, purchased those that died. An anatomical account of their electrical organs was drawn up by Mr Hunter, and published in the Philosophical Transactions. In the same volume there is a paper of his, containing experiments on animals and vegetables respecting their power of producing heat.

In the course of his pursuits, Mr Hunter met with many parts of animals where natural appearances could not be preserved, and others, in which the minuter vessels could not be distinctly seen when kept in spirits; it was therefore necessary to have them drawn, either at the moment, or before they were put into bottles.

The

Hunter. The expence of employing professed draughtsmen, the difficulty of procuring them, and the disadvantage which they laboured under in being ignorant of the subject they were to represent, made him desirous of having an able person in his house entirely for that purpose.

With this view he engaged an ingenious young artist to live with him for ten years; his time to be wholly employed as a draughtsman, and in making anatomical preparations. This gentleman, whose name was Bell, soon became a very good practical anatomist, and from that knowledge was enabled to give a spirited and accurate resemblance of the subjects he drew, such as is rarely to be met with in representations of anatomical subjects. By his labours Mr Hunter's collection is enriched with a considerable number of very valuable drawings, and a great variety of curious and delicate anatomical preparations.

In January 1776, Mr Hunter was appointed surgeon extraordinary to his Majesty; and in the spring he gave to the Royal Society a paper on the best mode of recovering drowned persons.

In the autumn he was taken extremely ill; and the nature of his complaints made his friends, as well as himself, consider his life to be in danger. When he reflected upon his own situation, that all his fortune had been expended in his pursuits, and that his family had no provision but what should arise from the sale of his collection, he became very solicitous to give it its full value, by leaving it in a state of arrangement. This he accomplished with the assistance of Mr Bell and his brother-in-law Mr Home.

In 1778, he published the second part of his Treatise on the Teeth, in which their diseases, and the mode of treatment are considered. This rendered his work upon that subject complete. He published also in the Philosophical Transactions a paper on the Heat of Animals and Vegetables. In 1779, he published his account of the Free Martin in the Philosophical Transactions; and in 1780, he laid before the Royal Society an account of a woman who had the small pox during pregnancy, where the disease seemed to have been communicated to the fœtus.

In 1781, he was elected a fellow of the Royal Society of Sciences and Belles Lettres at Gottenburg. And in 1782, he gave the Royal Society a paper on the Organ of Hearing in Fish. Besides the papers which he presented to that learned body, he read six Croonian lectures upon the subject of Muscular Action, for the years 1776, 1778, 1779, 1780, 1781, and 1782. In these lectures he collected all his observations, upon muscles, respecting their powers and effects, and the stimuli by which they are affected; and to these he added Comparative Observations upon the moving Powers of Plants.

These lectures were not published in the Philosophical Transactions, for they were withdrawn as soon as read, not being considered by the author as complete dissertations, but rather as materials for some future publication.

It is much to be regretted (says Mr Home) that Mr Hunter was so tardy in giving his observations to the public; but such was his turn for investigation, and so extensive the scale upon which he instituted his inquiries, that he always found something more to be accomplished, and was unwilling to publish any thing which

appeared to himself unfinished. His observations on the Muscular Action of the Blood-vessels were laid before the Royal Society in 1780, and yet he delayed publishing them till his Observations on the Blood and Inflammation were arranged; and they make part of the volume which was published after his death.

In 1783, he was chosen into the Royal Society of Medicine and the Royal Academy of Surgery in Paris; and the same year the lease of the house which he occupied in Jermyn-street having expired, he purchased the lease of a large house on the east-side of Leicester-square, and the whole lot of ground adjoining to Castle-street, on which there was another house. In the middle space between the two houses, he erected, at the expence of L. 3000, a building for his collection; though, unfortunately for his family, the lease did not extend beyond 24 years.

In the building formed for the collection there was a room fifty-two feet long by twenty-eight feet wide, lighted from the top, and having a gallery all round, for containing his preparations. Under this were two apartments; one for his lectures, and the other, with no particular destination at first, but afterwards made use of for weekly meetings of medical friends during the winter. To this building the house in Castle-street was entirely subservient; and the rooms in it were used for the different branches of human and comparative anatomy.

About this period Mr Hunter may be considered as at the height of his chirurgical career; his mind and body were both in their full vigour. His hands were capable of performing whatever was suggested by his mind; and his judgment was matured by former experience. Some instances of his extraordinary skill may very properly be mentioned.

He removed a tumor from the side of the head and neck of a patient at St George's Hospital, as large as the head to which it was attached; and by bringing the cut edges of the skin together, the whole was nearly healed by the first intention.

He dissected out a tumor on the neck, which one of the best operating surgeons in this country had declared, rather too strongly, that no one but a fool or a madman would attempt; and the patient got perfectly well.

He discovered a new mode of performing the operation for the popliteal aneurism, by taking up the femoral artery on the anterior part of the thigh, without doing any thing to the tumor in the ham. The safety and efficacy of this mode have been confirmed by many subsequent trials; and it must be allowed to stand very high among the modern improvements in surgery.

If we consider Mr Hunter at this period of his life, it will afford us a strong picture of the turn of his mind, of his desire to acquire knowledge, and his unremitting assiduity in prosecuting whatever was the object of his attention.

He was engaged in a very extensive private practice; he was surgeon to St George's Hospital; he was giving a very long course of lectures in the winter; he was carrying on his inquiries in comparative anatomy; had a school of practical human anatomy in his house; and was always employed in some experiments respecting the animal economy.

He was always solicitous for some improvement in medical

Hunter. medical education; and, with the assistance of Dr Fordyce, instituted a medical society, which he allowed to meet in his lecture rooms, and of which he was chosen one of the patrons. This society, called the *Lyceum Medicum Londinense*, under his auspices and those of Dr Fordyce, has acquired considerable reputation, both from the numbers and merits of its members.

In the year 1786, in consequence of the death of Mr Middleton, Mr Hunter was appointed deputy surgeon-general to the army. He now published his work upon the Venereal Disease, which had been long expected by the public; and, if we may judge from the rapid sale of the first edition, these expectations have not been disappointed. He also published a work entitled, *Observations on certain Parts of the Animal Economy*. In this work he has collected several of his papers inserted in the Philosophical Transactions, which related to that subject, having permission from the president and council of the Royal Society to reprint them; there are also Observations upon some other parts of the Animal Economy, which had not before been published. This work met with a very ready sale.

In the year 1787, he gave a paper to the Royal Society, containing an Experiment to determine the Effect of extirpating one Ovarium on the Number of Young; a paper in which the wolf, jackall, and dog, are proved to be of the same species; and a third upon the Anatomy of the Whale Tribe. These papers procured him the honour of receiving Sir John Copley's annual gold medal, given as a mark of distinguished abilities.

His collection, which had been the great object of his life, both as a pursuit and an amusement, was now brought into a state of arrangement; and gave him at length the satisfaction of shewing to the public a series of anatomical facts formed into a system, by which the economy of animal life was illustrated. He shewed it to his friends and acquaintances twice a-year, in October to medical gentlemen, and in May to noblemen and gentlemen, who were only in town during the spring. This custom he continued to his death.

Upon the death of Mr Adair, which happened in the year 1792, Mr Hunter was appointed inspector-general of hospitals, and surgeon-general to the army. He was also elected a member of the Royal College of Surgeons in Ireland. In the year 1791, he was so much engaged in the duties of his office, as surgeon-general to the army, and his private practice, that he had little time to bestow upon his scientific objects; but his leisure time, small as it was, he wholly devoted to them.

In 1792, he was elected an honorary member of the Chirurgo-Physical Society of Edinburgh, and was chosen one of the vice-presidents of the Veterinary College, then first established in London. He published in the Transactions of the Society for the Improvement of medical and surgical Knowledge, of which society he was one of the original members and a zealous promoter, three papers on the following subjects: Upon the Treatment of Inflamed Veins, on Introsusception, and on a Mode of conveying Food into the Stomach in Cases of Paralysis of the Oesophagus.

He finished his Observations on the Economy of Bees, and presented them to the Royal Society. These observations were made at Earl's Court, and had engaged his attention for many years; every inquiry into the economy of these insects had been attended by almost

unfathomable difficulties; but these proved to him only an incitement, and the contrivances he made use of to bring the different operations of these indefatigable animals to view were almost without end.

Earl's Court to Mr Hunter was a retirement from the fatigues of his profession; but in no respect a retreat from his labours; there, on the contrary, they were carried on with less interruption, and with an unwearied perseverance. From the year 1772 till his death, he made it his custom to sleep there during the autumn months, coming to town only during the hours of business in the forenoon, and returning to dinner.

It was there he carried on his experiments on digestion, on exfoliation, on the transplanting of teeth into the combs of cocks, and all his other investigations on the animal economy, as well in health as in disease. The common bee was not alone the subject of his observation, but the wasp, hornet, and the less known kinds of bees, were also objects of his attention. It was there he made the series of preparations of the external and internal changes of the silk worm; also a series of the incubation of the egg, with a very valuable set of drawings of the whole series. The growth of vegetables was also a favourite subject of inquiry, and one on which he was always engaged in making experiments.

The collection of comparative anatomy which Mr Hunter has left, and which may be considered as the great object of his life, must be allowed to be a proof of talents, assiduity, and labour, which cannot be contemplated without surprise and admiration. It remains an unequivocal test of his perseverance and abilities, and an honour to the country in whose schools he was educated, and by the patronage of which he was enabled on so extensive a scale to carry on his pursuits. In this collection we find an attempt to expose to view the gradations of Nature, from the most simple state in which life is found to exist, up to the most perfect and most complex of the animal creation—man himself.

By the powers of his art, this collector has been enabled so to expose, and preserve in spirits or in a dried state, the different parts of animal bodies intended for similar uses, that the various links of the chain of perfection are readily followed and may be clearly understood.

This collection of anatomical facts is arranged according to the subjects they are intended to illustrate, which are placed in the following order: *First*, Parts constructed for motion. *Secondly*, Parts essential to animals respecting their own internal economy. *Thirdly*, Parts superadded for purposes connected with external objects. *Fourthly*, Parts for the propagation of the species and maintenance or support of the young.

Mr Hunter was a very healthy man for the first forty years of his life; and, if we except an inflammation of his lungs in the year 1759, occasioned most probably by his attention to anatomical pursuits, he had no complaint of any consequence during that period. In the spring of 1769, in his forty first year, he had a regular fit of the gout, which returned the three following springs, but not the fourth; and in the spring of 1773, having met with something which very forcibly affected his mind, he was attacked at ten o'clock in the forenoon with a pain in the stomach, attended with all the symptoms of *angina pectoris*. In the life of him prefixed to his *Treatise on the Blood, Inflammation, and Gun-shot Wounds*,

Hunter

Wounds, the reader will find one of the most complete histories of that disease upon record. Suffice it, in this place, to say, that for twenty years he was subject to frequent and severe attacks of it, which however did not, till a short time before his death, either impair his judgment or render him incapable of performing operations in surgery. "In autumn 1790 (says Mr Home), and in the spring and autumn 1791, he had more severe attacks than during the other periods of the year, but of not more than a few hours duration: in the beginning of October 1792, one, at which I was present, was so violent that I thought he would have died. On October the 16th, 1793, when in his usual state of health, he went to St George's Hospital, and meeting with some things which irritated his mind, and not being perfectly master of the circumstances, he withheld his sentiments; in which state of restraint he went into the next room, and turning round to Dr Robertson, one of the physicians of the hospital, he gave a deep groan and dropt down dead; being then in his 65th year, the same age at which his brother Dr Hunter had died."

It is a curious circumstance, that the first attack of these complaints was produced by an affection of the mind, and every future return of any consequence arose from the same cause; and although bodily exercise, or distention of the stomach, brought on slighter affections, it still required the mind to be affected to render them severe; and as his mind was irritated by trifles, these produced the most violent effects on the disease. His coachman being beyond his time, or a servant not attending to his directions, brought on the spasms, while a real misfortune produced no effect.

Mr Hunter was of a short stature, uncommonly strong and active, very compactly made, and capable of great bodily exertion. His countenance was animated, open, and in the latter part of his life deeply impressed with thoughtfulness. When his print was shewn to Lavater, he said, "That man thinks for himself." In his youth he was cheerful in his disposition, and entered into youthful follies like others of the same age; but wine never agreed with his stomach; so that after some time he left it off altogether, and for the last twenty years drank nothing but water.

His temper was very warm and impatient, readily provoked, and, when irritated, not easily soothed. His disposition was candid, and free from reserve, even to a fault. He hated deceit; and as he was above every kind of artifice, he detested it in others, and too openly avowed his sentiments. His mind was uncommonly active; it was naturally formed for investigation, and that turn displayed itself on the most trivial occasions, and always with mathematical exactness. What is curious, it fatigued him to be long in a mixed company which did not admit of connected conversation; more particularly during the last ten years of his life.

He required less relaxation than most other men; seldom sleeping more than four hours in the night, but almost always nearly an hour after dinner; this, probably, arose from the natural turn of his mind being so much adapted to his own occupations, that they were in reality his amusement, and therefore did not fatigue.

In private practice he was liberal, scrupulously honest in saying what was really his opinion of the case, and ready upon all occasions to acknowledge his ignorance, whenever there was any thing which he did not understand.

In conversation, he spoke too freely, and sometimes harshly, of his contemporaries; but if he did not do justice to their undoubted merits, it arose not from envy, but from his thorough conviction that surgery was as yet in its infancy, and he himself a novice in his own art; and his anxiety to have it carried to perfection, made him think meanly and ill of every one whose exertions in that respect did not equal his own.

HUNTERS, in fortification, denote pieces of timber, about six inches square, placed at the lower end of the platform, next to the parapet, to prevent the wheels of the gun-carriages from damaging the parapet.

HYDROGRAPHICAL CHARTS or MAPS, more usually called sea-charts, are projections of some part of the sea, or coast, for the use of navigation. In these are laid down all the rhumbs or points of the compass, the meridians, parallels, &c. with the coasts, capes, islands, rocks, shoals, shallows, &c. in their proper places, and proportions.

HYDROMETER, is an instrument, of which so much has been said in the *Encycl.* under that title, and in the article *SPECIFIC GRAVITY*, that we certainly should not again introduce it in this place, but to guard our readers against error, when studying the works of the French chemists. These gentlemen, who are so strongly attached to every thing which is new, as to believe that their ancestors have for ages been wandering in the mazes of ignorance, refer very frequently to the *pefe-liqueur* of Baumé; and as that instrument has never been generally used in this country, it becomes our duty to describe its construction.

Instead of adopting the simpler method of immediate numerical reference to the density of water expressed by unity, as is done in all modern tables of specific gravity, he had recourse to a process similar to that of graduating the stems of thermometers from two fixed points. The first of these points was obtained by immersing his instrument, which is the common areometer, consisting of a ball, stem, and counterpoise, in pure water. At that point of the stem which was intersected by the surface of the fluid, he marked *zero*, or the commencement of his graduations. In the next place, he provided a number of solutions of pure dry common salt in water: these solutions contained respectively one, two, three, four, &c. pounds of the salt; and in each solution the quantity of water was such, as to make up the weight equal to one hundred pounds in the whole; so that in the solution containing one pound of salt, there were ninety-nine pounds of water; in the solution containing two pounds of salt, there were ninety-eight pounds of water, and so of the rest. The instrument was then plunged in the first solution, in which of course it floated with a larger portion of the stem above the fluid, than when pure water was used. The fluid, by the intersection of its surface upon the stem, indicated the place for making his first degree; the same operation repeated, with the fluid containing two pounds of salt, indicated the mark for the second degree; the solution of three pounds afforded the third degree; and in this manner his enumeration was carried as far as fifteen degrees. The first fifteen degrees afterwards, applied with the compasses repeatedly along the stem, serving to extend the graduation as far as eighty degrees, if required.

This instrument, which is applicable to the admeasurement

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Hydrome-
ter.

Hydrus, Hygrometer. furement of densities exceeding that of pure water, is commonly distinguished by the name of the *Hydrometer for salts*.

The hydrometer for spirits is constructed upon the same principle; but in this the counterpoise is so adjusted, that most part of the stem rises above the fluid when immersed in pure water, and the graduations to express inferior densities are continued upwards. A solution of ten parts by weight of salt in ninety parts of pure water, affords the first point, or zero, upon the stem; and the mark indicated by pure water is called the tenth degree; whence, by equal divisions, the remaining degrees are continued upwards upon the stem as far as the fiftieth degree.

These experiments, in both cases, are made at the tenth degree of Reaumur, which answers very nearly to fifty-five of Fahrenheit.

HYDRUS, or WATER SERPENT, one of the new southern constellations, including only ten stars.

HYGROMETER, is an instrument of so much importance to the meteorologist, that it becomes us to give some account of every improvement of it which has fallen under our notice. In the *Encyclopedia*, the principles upon which hygrometers are constructed have been clearly stated, and the defects of each kind of hygrometer pointed out.

Instead of hairs or cat-gut, of which hygrometers of the first kind are commonly made, Cassebois, a Benedictine monk at Mentz, proposed to make such hygrometers of the gut of a silk-worm. When that insect is ready to spin, there are found in it two vessels proceeding from the head to the stomach, to which they adhere, and then bend towards the back, where they form a great many folds. The part of these vessels next the stomach is of a cylindrical form, and about a line in diameter. These vessels contain a gummy sort of matter from which the worm spins its silk; and, though they are exceedingly tender, means have been devised to extract them from the insect, and to prepare them for the above purpose. When the worm is about to spin, it is thrown into vinegar, and suffered to remain there twenty-four hours; during which time the vinegar is absorbed into the body of the insect, and coagulates its juices. The worm being then opened, both the vessels, which have now acquired strength, are extracted; and, on account of their pliability, are capable of considerable extension. That they may not, however, become too weak, they are stretched only to the length of about fifteen or twenty inches. It is obvious that they must be kept sufficiently extended till they are completely dry. Before they attain to that state, they must be freed, by means of the nail of the finger, from a slimy substance which adheres to them. Such a thread will sustain a weight of six pounds without breaking, and may be used for an hygrometer in the same manner as cat-gut; but we confess that we do not clearly perceive its superiority.

To an improvement of the hygrometer constructed on the third principle, stated in the *Encyclopedia*, M. Hochheimer was led in the following manner:

Mr Lowitz found at Dmitriewik in Astracan, on the banks of the Wolga, a thin bluish kind of slate which attracted moisture remarkably soon, but again suffered it as soon to escape. A plate of this slate

Hygrometer. weighed, when brought to a red heat, 175 grains, and, when saturated with water, 247: it had therefore imbibed, between complete dryness and the point of complete moisture, 72 grains of water. Lowitz suspended a round thin plate of this slate at the end of a very delicate balance, fastened within a wooden frame, and suspended at the other arm a chain of silver wire, the end of which was made fast to a sliding nut that moved up and down in a small groove on the edge of one side of the frame. He determined, by trial, the position of the nut when the balance was in equilibrium and when it had ten degrees of over-weight, and divided the space between these two points into ten equal parts, adding such a number more of these parts as might be necessary. When the stone was suspended from the one arm of the balance, and at the other a weight equal to 175 grains, or the weight of the stone when perfectly dry, the nut in the groove shewed the excess of weight in grains when it and the chain were so adjusted that the balance stood in equilibrium. A particular apparatus on the same principles as a vernier, applied to the nut, shewed the excess of weight to ten parts of a grain. Lowitz remarked that this hygrometer in continued wet weather gave a moisture of more than 55 grains, and in a continued heat of 113 degrees of Fahrenheit only $1\frac{1}{2}$ degree of moisture.

The hygrometer thus invented by Lowitz was, however, attended with this fault, that it never threw off the moisture in the same degree as the atmosphere became drier. It was also sometimes very deceitful, and announced moisture when it ought to have indicated that dryness had again begun to take place in the atmosphere. To avoid these inconveniences, M. Hochheimer proposes the following method:

1. Take a square bar of steel about two lines in thickness, and from ten to twelve inches in length, and form it into a kind of balance, one arm of which ends in a screw. On this screw let there be screwed a leaden bullet of a proper weight, instead of the common weights that are suspended.
2. Take a glass plate about ten inches long, and seven inches in breadth, destroy its polish on both sides, free it from all moisture by rubbing it over with warm ashes, suspend it at the other end of the balance, and bring the balance into equilibrium by screwing up or down the leaden bullet.
3. Mark now the place to which the leaden bullet is brought by the screw, as accurately as possible, for the point of the greatest dryness.
4. Then take away the glass plate from the balance, dip it completely in water, give it a shake that the drops may run off from it, and wipe them carefully from the edge.
5. Apply the glass plate thus moistened again to the balance, and bring the latter into equilibrium by screwing the leaden bullet. Mark then the place at which the bullet stands as the highest degree of moisture.
6. This apparatus is to be suspended in a small box of well dried wood, sufficiently large to suffer the glass plate to move up and down. An opening must be made in the lid, exactly of such a size as to allow the tongue of the balance to move freely. Parallel to the tongue apply a graduated circle, divided into a number of degrees at pleasure from the highest point of dryness to the highest degree of moisture. The box must be pierced with small holes on all the four sides, to give a free passage to the air; and to prevent moisture from penetrating into

Hypomet. into the wood by rain, when it may be requisite to expose it at a window, it must either be lackered or painted. To save it at all times from rain, it may be covered, however, with a sort of roof fitted to it in the most convenient manner. But all these external appendages may be improved or altered as may be found necessary.

HYPERBOLA DEFICIENT, is a curve having only

one asymptote, though two hyperbolic legs running out infinitely by the side of the asymptote, but contrary ways.

HYPOTRACHELION, in Architecture, is used for a little frieze in the Tuscan and Doric capital, between the astragal and annulets; called also the colerin and gorgerin. The word is applied by some authors in a more general sense, to the neck of any column, or that part of its capital below the astragal.

Hypotrachelion.

I.

Jacobins. JACOBINS, in the language of the present day, is the name assumed, at the beginning of the French revolution, by a party in Paris, which was outrageously democratical, and fanatically impious. This party, which consisted of members of the National Assembly, and of others maintaining the same opinions and pursuing the same objects, formed itself into a club, and held its meetings in the hall belonging to the Jacobin friars, where measures were secretly concerted for exciting insurrections, and over-awing at once the legislature and the king. The name of *Jacobin*, though it was derived from the hall where the club first met, has since been extended to all who are enemies to monarchy, aristocracy, and the Christian religion; and who would have every man to be his own priest and his own lawgiver. Hence it is, that we have Jacobins in Great Britain and Ireland, as well as in France.

Of the proceedings of the French Jacobins, some account has been given in the *Encyclopædia*, under the title REVOLUTION; and the subject will be resumed in this *Supplement* under the same title. The purpose of the present article is to trace the principles of the sect from their source; for these principles are not of yesterday.

“At its very first appearance (says the Abbé Barruel), this sect counted 300,000 adepts; and it was supported by two millions of men, scattered through France, armed with torches and pikes, and all the firebrands of the revolution.” Such a wide spread conspiracy could not be formed in an instant; and indeed this able writer has completely proved, that this sect, with all its conspiracies, is in itself no other than “the coalition of a triple sect, of a triple conspiracy, in which, long before the revolution, the overthrow of the altar, the ruin of the throne, and the dissolution of all civil society, had been debated and determined.”

It is known to every scholar, that there have been in all ages and countries men of letters and pretenders to letters, who have endeavoured to signalize themselves individually by writing against the religion of their country; but it was reserved for the philosophists (A) of France to enter into a combination for the express purpose of eradicating from the human heart every religious sentiment. The man to whom this idea first occurred

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red was Voltaire; who, daring to be jealous of his God, and being weary, as he said himself, of hearing people repeat that twelve men were sufficient to establish Christianity, resolved to prove that one might be sufficient to overthrow it. Full of this project, he swore, before the year 1730, to dedicate his life to its accomplishment; and for some time he flattered himself that he should enjoy alone the glory of destroying the Christian religion. He found, however, that associates would be necessary; and from the numerous tribe of his admirers and disciples, he chose D’Alembert and Diderot as the most proper persons to co-operate with him in his designs. How admirably they were qualified to act the part assigned them, may be conceived from the life of DIDEROT in this *Supplement*. But Voltaire was not satisfied with their aid alone.

Jacobins.

He continued to embark in the same cause Frederic II. of Prussia, who wished to be thought a philosopher, and who of course deemed it expedient to talk and write against a religion which he had never studied, and into the evidence of which he had probably never deigned to inquire. This royal adept was one of the most zealous of Voltaire’s coadjutors, till he discovered that the philosophists were waging war with the throne as well as with the altar. This indeed was not originally Voltaire’s intention. He was vain; he loved to be caressed by the great; and, in one word, he was, from natural disposition, an aristocrate and admirer of royalty: But when he found that almost every sovereign but Frederic, disapproved of his impious projects as soon as he perceived their issue, he determined to oppose all the governments on earth, rather than forfeit the glory, with which he had flattered himself, of vanquishing Christ and his apostles in the field of controversy.

He now set himself, with D’Alembert and Diderot, to excite universal discontent with the established order of things. This was an employment entirely suited to their disposition; for not being in any sense great themselves (B), they wished to pull all men down to their own level. How effectually they contrived to convert the *Encyclopédie* into an engine to serve their purposes, has been shewn already; but it was not their only nor their most powerful engine; they formed secret societies,

5 D

ties,

(A) This term was invented by Abbé Barruel, and we have adopted it, as denoting something very different from the meaning of the word *philosopher*.

(B) We do not by this mean to insinuate that D’Alembert was not a man of science. He was perhaps the only man of science in that gang; but he was a master of no science but mathematics; and his birth being obscure,

Jacobins.

ties, assumed new names, and employed an enigmatical language. Thus, Frederic is called *Luc*; D'Alembert, *Protagoras*, and sometimes *Bertrand*; Voltaire, *Raton*; and Diderot, *Platon*, or its anagram *Tonpla*; while the general term for the conspirators is *Cacouce*. In their secret meetings they professed to celebrate the mysteries of *Mybra*; and their great object, as they professed to one another, was to confound the *wretch*, meaning J—C—. Voltaire proposed to establish a colony of philosophers at Cleves, who, protected by the king of Prussia, might publish their opinions without dread or danger; and Frederic was disposed to take them under his protection, till he discovered that their opinions were anarchical, as well as impious, when he threw them off, and even wrote against them.

They contrived, however, to engage the ministers of the court of France in their favour, by pretending to have nothing in view but the enlargement of science, in works which spoke indeed respectfully of revelation, while every discovery which they brought forward was meant to undermine its very foundation. When the throne was to be attacked, and even when barefaced atheism was to be promulgated, a number of impious and licentious pamphlets were dispersed, for some time none knew how, from a secret society formed at the Hotel d'Holbach at Paris. These were sold for trifles, or distributed *gratis* to schoolmasters, and others who were likely to circulate their contents. D'Alembert, Diderot, and Condorcet, who was now associated with the other conspirators, flattered the ambition of every man among the great, and especially of the Duke d'Orleans, the richest subject in Europe, and a prince of the blood of France. The first and the last of these three adepts had, by their mathematical knowledge, got such an ascendancy in the Royal Academy of Sciences, that they could admit or exclude candidates as they knew them to be friendly or inimical to the projects of the conspirators; and they had contrived, by matchless address and unwearied perseverance, to fill almost all the seminaries of education with men of their own principles.

Thus was the public mind in France completely corrupted, when the mason lodges, over which the infamous Orleans presided, were visited by a delegation from the German illuminati; and nothing more was necessary to produce the sect of *Jacobins*, by whose intrigues and influence, France, as M. Barruel expresses himself, has become a prey to every crime. It was by the machinations of this sect that its soil was stained with the blood of its pontiffs and priests, its rich men and nobles; with the blood of every class of its citizens, without regard to rank, age, or sex. These disciples of Voltaire were the men who, after having made the unfortunate Louis, his queen, and sister, drink, to the very dregs, the cup of outrage and ignominy during a long confinement, solemnly murdered them on a scaffold, proudly menacing all the sovereigns of the earth with a similar fate. Yet think not, indignant reader, that the ways of Providence are unequal. The nations of Europe were ripe for chastisement; and that chastisement these villains were employed to inflict: but their own punishment did not linger. Voltaire died in agonies of de-

sponding remorse, which can be exceeded only by the torments of the damned. There is reason to believe that the end of D'Alembert and Diderot very much resembled that of their leader; while the more hardened adept, Condorcet, became his own executioner; and the other chiefs of the rebellion have regularly inflicted vengeance on each other, every alteration of the French constitution (and these alterations have been many) being followed by the execution of those by whom the government was previously administered.

JAGHIRE, assignment made in Bengal by an Imperial grant upon the revenue of any district, to defray civil or military charges, pensions, gratuities, &c.

JAGHIREDER, the holder of a Jaghire.

ST JAGO, the largest and most populous of the Cape de Verde Islands, of which some account has been given in the *Encyclopaedia*, is represented by Sir George Staunton as liable to long and excessive droughts, for which no philosophical cause can be assigned. When the embassy to China touched at it in the latter end of 1792, it was in a state of absolute famine. Little or no rain had fallen for about three years before. The rivers were almost all entirely dry. The surface of the earth was, in general, naked of any herbage. The greatest part of the cattle had perished, not less through drought than want of food. Of the inhabitants many had migrated, and many were famished to death. Nor was this calamity peculiar to St Jago. All the islands of Cape de Verde were said to have experienced the same long drought, and to be consequently in a state of similar desolation. Yet the frequent showers which were observed by the first navigators who touched at St Jago, induced them to give to the island the name of *Pluvialis*; and no change had been observed in the steady current of wind, blowing from the east, which is common to tropical climates.

“What were the uncommon circumstances (says Sir George) that took place in the atmosphere of that part of Africa to which the Cape de Verde islands lie contiguous, or in the vast expanse of continent extending to the east behind it, and from which this direful effect must have proceeded, as they happened where no man of science existed to observe or to record them, will therefore remain unknown; nor is theory bold enough to supply the place of observation. Whatever was the cause which thus arrested the bountiful hand of Nature, by drawing away the sources of fertility, it was observable, that some few trees and plants persevered to flourish with a luxuriance, indicating that they still could extract from the arid earth whatever portion of humidity it was necessary to derive from thence for the purpose of vegetable life, though it was denied to others.”

Beside the trees of the palm kind, which are often found verdant amidst burning sands, nothing, for example, could be more rich in flavour, or abound more with milky, though corrosive juice, than the *asclepias gigantea* (see *ASCLEPIAS*, *Encycl.*), growing plentifully, about several feet high, without culture, indeed, but undisturbed, it being of no avail to cut it down in favour of plants that would be useful, but required the aid of more moisture from the atmosphere. The *jatropha*

Jaghire
||
Jago.

scure, if not spurious, and abstract mathematics not furnishing ready access to the great, his ideas, when compared with Voltaire's, were grovelling, and (as M. Barruel says) he was afraid to be seen.

Jago. pha curcas, or physic nut tree, which the French West Indians, with some propriety, call *hois immortel*, and plant, on that account, in the boundaries of their estates, appeared as if its perpetuity was not to be affected by any drought. Some indigo plants were still cultivated with success in shaded vales, together with a few cotton shrubs. Throughout the country some of those species of the mimosa, or sensitive plant, which grow into the size of trees, were most common, and did not appear to languish. In particular spots the amona, or sugar apple tree, was in perfect verdure. The borassus, or great fan palm, lifted, in a few places, its lofty head and spreading leaves with undiminished beauty. In a bottom, about a mile and a half behind the town of Praya, was still growing, in a healthy state, what may be called for size a phenomenon in vegetation, a tree known to botanists by the name of *adanfonia*, and in English called *monkey bread tree*. The natives of St Jago call it *kabifera*; others, baobab. Its trunk measured at the base no less than 56 feet in girth; but it soon divided into two great branches, one rising perpendicularly, and measuring 42 feet in circumference; that of the other was about 26. By it stood another of the same species, whose single trunk, of 38 feet girth, attracted little notice from the vicinity of its huge companion.

But the annual produce of agriculture was scarcely to be found. The plains and fields, formerly productive of corn, sugar-canes, or plantains, nourished by regular falls of rain, now bore little semblance of vegetation. Yet in the small number of plants which survived the drought, were some which, from the specimens sent to Europe, were found to have been hitherto unknown. Vegetation quickly, indeed, revived wherever, through the soil, any moisture could be conveyed.

Sir George represents Praya, the residence of the Portuguese Viceroy, as a hamlet rather than a town. It consists of about 100 very small dwellings, one story high, scattered on each side of the plain, which extended near a mile in length, and about the third of a mile in breadth; and fell off, all around, to the neighbouring valleys and to the sea. Not being commanded by any neighbouring eminence, it was a situation capable of defence; the fort, however, or battery, was almost in ruins; and the few guns mounted on it were mostly honey-combed, and placed on carriages which scarcely held together.

A party belonging to the embassy crossed the country to the ruins of St Jago, the former capital of the island, situated in the bottom of a vale, through which ran a stream, then both small and sluggish. On each side of that stream are the remains of dwellings of considerable solidity and size; and the fragments of glass lustres, still hanging from the ceilings of some of the principal apartments, denote the elegance or riches that were once displayed in this now deserted place. Not above half a dozen families remain in it at present; the rest abandoned it, or perished. Here was still, however, an attempt at a slight manufactory of stripped cotton slips, the same as are made in the other parts of the island, for the use of the Africans on the main, who pay for them in slaves, elephants teeth, and that gum which is generally called arabic.

Amidst the ruins of St Jago, the party found a Portuguese, to whom one of them was recommended, and

who received them with the most cordial hospitality in his house, and treated them with every species of tropical fruits from his garden, lying on each side the river.

He had been a navigator; and informed them that the isle of Brava, one of the Cape de Verde's, was a fitter and safer place for ships to call at for water and provisions than the island of St Jago; that it had three harbours: one called Puerto Furro on the east side of the island, from which vessels must warp, or be towed out by boats; the Puerto Fajendago to the west; and the Puerto Ferreo to the south, which was the best for large ships, and into which runs a small river. In another of the Cape de Verde islands, called San Vicente, he observed that there was also a large harbour on the north end, but that fresh water was at some distance from it: and there was likewise a good port at Bonavista. This information of the harbours in the isle of Brava was confirmed by accounts given by others to Sir Erasmus Gower, who recommends to make a trial of them.

JALOFFS, or YALOFFS, are an active, powerful, and warlike people, inhabiting great part of that tract of Africa which lies between the Senegal and the Mandingo states on the Gambia (See MANDINGOES in this Supplement). Their noses, says Mr Park, are not so much depressed, nor their lips so protuberant, as those of the generality of Africans; and though their skin is of the deepest black, they are considered by the white traders as the most slightly negroes in that part of the continent where they live. They are divided into several independent states or kingdoms, which are frequently at war with their neighbours or with each other. In their manners, superstitions, and government, they have a greater resemblance to the Mandingoes than to any other nation; but excel them in the manufacture of cotton cloth, spinning the wool to a finer thread, weaving it in a broader loom, and dyeing it of a better colour. They make very good soap, by boiling ground nuts in water, and then adding a ley of wood ashes. They likewise manufacture excellent iron, which they carry to Bondou to barter for salt. Their language is said to be copious and significant, and is often learned by Europeans trading to Senegal. From the names of their numerals, as given by Mr Park, it would appear that their numeration proceeds by *fives*, as ours does by *tens*.

Our author relates the event of a religious war, which, as it displays a generosity of character very uncommon among savages, will afford pleasure to the minds of many of our readers. Almami Abdulkader, sovereign of a Mahomedan kingdom called Foota Torra, sent to Damel, a king of the Jaloffs, an imperious message, commanding him and his subjects to embrace instantly the faith of the prophet. The ambassador having got admission to the presence of Damel, ordered some Bushreens (*i. e.* Mahomedan negroes) who accompanied him, to present the emblems of his mission. Two knives were accordingly laid before the Jaloff prince, and the ambassador explained himself as follows:

“With this knife (said he) Abdulkader will condescend to shave the head of Damel, if Damel will embrace the Mahomedan faith; and with this other knife Abdulkader will cut the throat of Damel, if Damel refuses to embrace it: Take your choice.”—Damel coolly told the ambassador that he had no choice to make;

Jaloffs,
Jarra.

he neither chose to have his head shaved, nor his throat cut. And with this answer the ambassador was civilly dismissed.

Abdulkader took his measures accordingly; and with a powerful army invaded Damel's country. The inhabitants of the towns and villages filled up their wells, destroyed their provisions, carried off their effects, and abandoned their dwellings, as he approached. By this means he was led on from place to place, until he had advanced three days journey into the country of the Jaloffs. He had, indeed, met with no opposition; but his army had suffered so much from the scarcity of water, that several of his men died by the way. This induced him to direct his march towards a watering place in the woods, where his men, having quenched their thirst, and being overcome with fatigue, lay down carelessly to sleep among the bushes. In this situation they were attacked by Damel before day-break, and completely routed. Many of them were trampled to death as they lay asleep by the Jaloffs' horses; others were killed in attempting to make their escape; and a still greater number were taken prisoners. Among the latter was Abdulkader himself. This ambitious, or rather frantic prince, who, but a month before, had sent the threatening message to Damel, was now himself led into his presence as a miserable captive. The behaviour of Damel, on this occasion, is never mentioned by the singing men* but in terms of the highest approbation; and it was, indeed, so extraordinary in an African prince, that the reader may find it difficult to give credit to the recital. When his royal prisoner was brought before him in irons, and thrown upon the ground, the magnanimous Damel, instead of setting his foot upon his neck, and stabbing him with his spear, according to the custom in such cases, addressed him as follows: "Abdulkader, answer me this question. If the chance of war had placed me in your situation, and you in mine, how would you have treated me?" "I would have thrust my spear into your heart (returned Abdulkader with great firmness); and I know that a similar fate awaits me." "Not so (said Damel); my spear is indeed red with the blood of your subjects killed in battle, and I could now give it a deeper stain, by dipping it in your own; but this would not build up my towns, nor bring to life the thousands who fell in the woods. I will not therefore kill you in cold blood, but I will retain you as my slave, until I perceive that your presence in your own kingdom will be no longer dangerous to your neighbours; and then I will consider of the proper way of disposing of you." Abdulkader was accordingly retained, and worked as a slave for three months; at the end of which period, Damel listened to the solicitations of the inhabitants of Foota Torra, and restored to them their king. Strange as this story may appear, Mr Park has no doubt of the truth of it. It was told to him at Malacotta by the negroes; it was afterwards related to him by the Europeans on the Gambia; by some of the French at Goree; and confirmed by nine slaves, who were taken prisoners along with Abdulkader by the watering place in the woods, and carried in the same ship with him to the West Indies.—Such generosity as this reflects honour on human nature.

JARRA, is a town of considerable extent in the Moorish kingdom of Ludamar in Africa. The houses

are built of clay and stone intermixed, a kind of wall very common in many parts of Scotland, where clay is made to supply the place of mortar. The greater part of the inhabitants of Jarra are Negroes from the borders of the southern states, who prefer, says Mr Park, a precarious protection under the Moors, which they purchase by a tribute, to the being continually exposed to their predatory hostilities. The tribute which they pay is considerable; and they manifest the most unlimited obedience and submission to their Moorish superiors: by whom they are, in return, treated with the utmost indignity and contempt. The Moors in this, and the other states adjoining the country of the Negroes, resemble in their persons the Mulattoes of the West Indies, and seem to be a mixed race between the Moors, properly so called, of the north, and the Negroes of the south; possessing many of the worst qualities of both nations. Jarra is situated in 15° 5' N. Lat. and 6° 48' E. Long.

IBIS. Under the generic name TANTALUS (*Encycl.*), we have described, after Mr Bruce, a bird which he found in Abyssinia, and concluded to be the sacred ibis of ancient Egypt. M. Vaillant, during his last travels in Africa, found, in some lakes near the elephants river, a bird very different from Mr Bruce's, which he considered as belonging to the same species; and which he describes thus: It is three feet in height. Its head and throat, which are extremely bare, are covered with a skin of the brightest red, terminated by a band of a beautiful orange, which separates the naked part from that covered with feathers. The upper part of the wings, having broad stripes of a fine violet colour, agreeably shaded, is bordered by a white band of feathers, the thick and silky beards of which, separated from each other, have a perfect resemblance to a rich fringe. The quills of the wings and tail are of a greenish black, which, as it receives the light in a more or less oblique direction, assumes the appearance of violet or purple. The rest of the plumage is of a beautiful white. The bill, which is long and somewhat crooked, is yellow; as are the feet. This bird belongs to the genus of the ibis, of which we are already acquainted with several species.

ICE-HOUSE. See that article, *Encyclopaedia*. Professor Beckmann, in the third volume of his History of Inventions, has proved clearly that the ancients were well acquainted with what served the purpose of ice-houses.

"The art (says he) of preserving snow for cooling liquors during the summer, in warm countries, was known in the earliest ages. This practice is mentioned by Solomon*, and proofs of it are so numerous in the works of the Greeks and the Romans, that it is unnecessary for me to quote them, especially as they have been collected by others. How the repositories for keeping it were constructed, we are not expressly told; but it is probable that the snow was preserved in pits or trenches.

"When Alexander the Great besieged the city of Petra, he caused 30 trenches to be dug, and filled with snow, which was covered with oak branches; and which kept in that manner for a long time. Plutarch says, that a covering of chaff and coarse cloth is sufficient; and at present a like method is pursued in Portugal. Where the snow has been collected in a deep gulph, some

* The historians of the country.

This, Ice-house.

* Proverbs, xxv. 15.

Ichnography, Jebb. some grafs or green fods, covered with dung from the sheep pens, is thrown over it; and under these it is so well-preserved, that the whole summer through it is sent the distance of 60 Spanish miles to Lisbon.

"When the ancients, therefore, wished to have cooling liquors, they either drank the melted snow, or put some of it in their wine, or they placed jars filled with wine in the snow, and suffered it to cool there as long as they thought proper. That ice was also preserved for the like purpose, is probable from the testimony of various authors; but it appears not to have been used so much in warm countries as in the northern. Even at present snow is employed in Italy, Spain, and Portugal; but in Persia ice. I have never any where found an account of Grecian or Roman ice-houses. By the writers on agriculture they are not mentioned."

ICHTNOGRAPHY, in architecture, is a transverse or horizontal section of a building, exhibiting the plot of the whole edifice, and of the several rooms and apartments in any story; together with the thickness of the walls and partitions; the dimensions of the doors, windows, and chimneys; the projectures of the columns and piers, with every thing visible in such a section.

JEBB (John), was born in Southampton-street, Covent Garden, London, on the 16th of February 1736. He was the eldest son of the Rev. John Jebb, dean of Cashel, in the kingdom of Ireland. He received the elements of his education in different schools, and was admitted, July 7. 1753, pensioner in the university of Dublin, whence he removed, November the 9th 1754, to St Peter's college in Cambridge, where he was likewise a pensioner. In January 1757 he proceeded to the degree of B. A. and his place in the distribution of academical honours was, on that occasion, second wrangler, the late eminent mathematician Dr Waring being the first. In 1758 he obtained the second prize of fifteen guineas, annually given by the university to the authors of the best compositions in Latin prose, being senior or middle bachelors of arts. Dr Roberts, afterwards provost of Eton college, obtained the first.

In the month of June 1760, Mr Jebb was admitted probationer fellow of St Peter's college, and proceeded to the degree of Master of Arts at the commencement in the same year; and on the first of July 1761, was confirmed fellow by Dr Mawson, bishop of Ely.

On the 6th of June 1762, he was ordained deacon at Bugden by Dr John Green, bishop of Lincoln; and on the 25th of September, 1763, he was admitted by the same bishop into priest's orders.

On the 22d of August, 1764, Mr Jebb was collated by Dr Matthias Mawson, bishop of Ely, to the small vicarage of Gamlingay, near Pottou, in Bedfordshire, upon the recommendation of Dr Law, master of Peterhouse. On the 17th of the following October, he was elected by the university into the rectory of Ovington, near Watton, in Norfolk, after a competition with the Rev. Henry Turner, then fellow of St John's college, afterwards vicar of Burwell, in Cambridgeshire. Upon casting up the votes, there appeared to be for Mr Jebb 91, for Mr Turner 73; and accordingly he was instituted into the same the 15th of December following.

On the 29th of the same month, (December 1764) Mr Jebb married Anne, eldest daughter of the Rev.

James Torkington, rector of Little Stukeley, in Huntingdonshire, and of lady Dorothy Sherard, daughter of Philip, second earl of Harborough.

Early in the year 1765, Mr Jebb, together with the Rev. Robert Thorpe, fellow of Peterhouse, and the Rev. George Woolston, fellow of Sidney college, published, in a small quarto, a comment on those parts of Sir Isaac Newton's *Principia* which more immediately relate to the system of the world. The title of the joint work, of these able and judicious philosophers was, "Excerpta quædam e Newtoni principiis philosophiæ naturalis, cum notis variorum." A work, of which the university of Cambridge continues to bear testimony to the excellence, by the general use of it in the course of academical education.

Mr Chappelow professor of Arabic, dying on the 14th of January 1768, Mr Jebb offered himself a candidate for the vacant chair; but it was given to Dr Hallifax, afterwards bishop of Gloucester; a man of deserved celebrity, of whom we regret that it was not in our power to give a biographical sketch.

On July 10. 1769, Mr Jebb was instituted to the vicarage of Flixton, near Bungay, in Suffolk, on the presentation of William Adair, Esq. of Flixton-hall; and on the 4th of April 1770, was instituted to the united rectories of Homersfield and St Cross, parishes contiguous to Flixton, upon the same presentation: being also, in the summer of the same year, nominated chaplain to Robert earl of Harborough. In consequence of the accession of these preferments, though not considerable in themselves, he resigned, some time in the month of October 1771, the rectory of Ovington, which he had received from the university; and Mr Sheephanks, fellow of St John's college, was elected in his place.

Dr Hallifax succeeding to the professorship of civil law, in the month of October 1770, upon the death of Dr Ridington, Mr Jebb once more solicited that of Arabic, which Dr Hallifax then vacated; but he had by this time displayed such an innovating spirit in religion, that the university gave the vacant professorship to Mr Craven, a man respected even by Mr Jebb and his friends.

Early in the year 1771, a design was formed of applying to parliament for relief in the matter of subscription to the liturgy, and thirty-nine articles of the Church of England; and in the prosecution of this design Mr Jebb took a very active part. He attended different meetings of the discontented clergy, held at the Feathers tavern, London, assisted in the drawing up of their petition, and wrote their circular letter, which gave to the public an account of their aims. He busied himself at the same time in making various attempts to bring about what he called a reformation of the university of Cambridge: but finding them fruitless, he retired, on the 25th of June 1772, to Bungay, where he studied French and Italian, and proceeded in a plan of some *political or constitutional lectures*.

He had by this time ceased to read the prayers of the church, though he still continued to preach occasionally; and the Archdeacon of Suffolk, holding, this year, his usual visitation of some neighbouring parishes in the church of Flixton, Mr Jebb preached such a sermon against subscription, as drew upon himself a public rebuke from the Archdeacon, in the presence of the clergy. "Much altercation, (says he) ensued; and

and for some days I expected a summons to Norwich; but have heard no more of it. *I acted thus, with a view to call the attention of the Norwich clergy to our cause; and have in part succeeded.*

He acted much more honourably than this, when, in 1775, he resigned all his preferments in the church; which surely he ought not to have retained one day after his conscience would not permit him to read the prayers of the liturgy. He now resolved to become a physician; and after attending St Bartholomew's hospital in London for six months, as the pupil of Dr William Pitcairn, he received, on the 18th of March 1777, a diploma of Doctor of Physic from the university of St Andrews!! He did not, however, commence practice till the 5th of February 1778; and even then he continued to attend the lectures of Dr Hunter, Mr John Hunter, and Dr Higgins. On the 18th of February 1779 he was elected a fellow of the Royal Society.

Dr Jebb, at the breaking out of the American war, had shewn himself at Cambridge a warm partizan of the revolting colonies; and of course a keen advocate for what he called, and, we doubt not, thought, the civil liberties of mankind. He now signalized himself by "An address to the Freeholders of Middlesex," assembled at Free mason's tavern in Great Queen-street, on Monday, December the 20th 1779, for the purpose of establishing meetings to maintain and support the freedom of election. Upon this occasion, he communicated to James Townsend, Esq. chairman of that meeting, the above address, under the signature of "Salus Publica;" presuming, that if the sentiments appeared to be founded in reason, they would not be the less regarded on account of their being suggested by an unknown individual."

This address was immediately printed, and very soon passed through three editions, each being enlarged by the addition of fresh matter; and in 1782, followed the fourth edition corrected, which also bore our author's name in the title page.

About the end of February 1780, Dr Jebb was appointed by the committee of the county of Huntingdon, one of their deputies, to attend a meeting in London of representatives from certain other petitioning counties, in order to concert measures for the more effectual reform of the present constitution of the house of commons. Soon afterwards he became one of the most active members of "the society for constitutional information;" of which the object, according to their own account, was to diffuse throughout the kingdom, as universally as possible, a knowledge of the great principles of constitutional freedom, particularly such as respect the election and duration of the representative body. "With this view (say they), constitutional tracts, intended for the extension of this knowledge, and to communicate it to persons of all ranks, are printed and distributed gratis, at the expence of the society. Essays, and extracts from various authors, calculated to promote the same design, are also published under the direction of the society, in several of the newspapers; and it is the wish of the society to extend this knowledge throughout every part of the united kingdoms, and to convince men of all ranks, that it is their interest, as well as their duty, to support a free constitution, and to maintain and assert those common rights,

which are essential to the dignity and to the happiness of human nature." Could Dr Jebb have foreseen all the mischiefs which have flowed from this institution; could he have foreseen the wonderful spawn of factious societies which have sprung from it as from a parent stock, our veneration for genius and learning will not permit us to believe, that he would have neglected the studies of his profession for the sake of taking the lead in party politics.

Dr Petit, one of the physicians of St Bartholomew's hospital, dying the 26th of May, Dr Jebb offered himself a candidate to succeed to that appointment. The election came on the 23d of June; when Dr Budd, his antagonist, succeeded by a great majority.

The opposition which was made to his election at St Bartholomew's, followed him in the winter, when he offered himself at St Thomas's hospital in the borough. Indeed he relinquished his pretensions there sooner than in the former place; but for no other reason than because he found that all his political principles were likely to be again objected to him, and to hazard his success.

In the year 1783 he concurred with others in forming "the society for promoting the knowledge of the scriptures," which met first on the 20th of September in that year, and whose meetings continued to be held, and, for ought we know to the contrary, are still held at Effex-house. The sketch of their plan was chiefly written by Dr Jebb; and their object was to propagate the doctrines of Unitarianism, for which he was as great a zealot as for civil liberty.

His health now began to decline; but during his confinement, he studied the Saxon language, the Anglo Saxon laws, English history and antiquities, with a view to examine into our criminal code, and particular points of liberty. The vigour of his mind was still equal to the furnishing himself with this fresh store of knowledge; he foresaw the advantage of such an acquisition in the investigation of the legal rights of Englishmen, and had designed to have employed it in the support of some great constitutional questions, which he considered as essential to the freedom of his country.

But as the year began to dawn, it was very observable to many of his friends that, according to every appearance, and without some very great and singular effort of nature, his increased debility would defeat every exertion of the most judicious medical assistance, and terminate the remaining sparks of human life.

In this enfeebled state, his mind was active. His "Thoughts on Prisons" were printed and circulated in the county of Suffolk in 1785, by his much valued friend Mr Lofft; and there is sufficient reason for concluding that this little tract had effect on the deliberations of the justices at Ipswich and Bury, then engaged in erecting a new gaol for the division of Ipswich, and a new house of correction for that of Bury.

The good effects of this very excellent tract, it was apprehended, would be extended by a more general publication. In this hope Dr Jebb revised and corrected it with his dying hand; and his surviving friend published it soon after his death, adding thereto "an abstract of felonies created by statute and other articles relative to the penal law.

He continued to linger till May the 2d 1786, when, about 8 o'clock in the evening, he breathed his last, leaving

Jeffersonia
Jerboa

leaving behind him, among men of different persuasions, very different characters. By the dissenters he is seldom mentioned but as the *Great Jebo*; by churchmen, his abilities are universally allowed, whilst regret is expressed that they were so often employed in support of faction and heresy. His moral character has never been aspersed.

JEFFERSONIA, a new plant lately discovered in Georgia by Dr. Brickel of Savannah, and so named by him in compliment to the vice president of the United States. In the *Monthly Magazine* for July 1798 we have the following description of it;

JEFFERSONIA pentendria monogynia.

Calyx, below, composed of five short oval imbricated leaves; *corolla*, monophyllous, funnel-shaped on the receptacle, sub-pentangular, bearing the filaments near the base, its margin hypocrateriform, divided into five round ducts nearly equal; *style*, pitiform, shorter than the petal, but longer than the stamens; *stigma*, quadripid; *anthers*, erect, linear, sagittated; *fruit*, two univalved, carinated, polyspermous capsules, united at the base, opening on their tops and contiguous sides, having flat seeds, with a marginal wing.

Only one species is as yet discovered, *Jeffersonia sempervirens*. It is a shrub with round polished twining stems, which climb up on bushes and small trees; the petioles short, opposite; leaves oblong, narrow, entire, evergreen, acute; flowers axillary, yellow, having a sweet odour. The woods are full of this delightful shrub, which is covered with blossoms for many months in the year.

JERBOA, see *Mos*, *Encycl*, where descriptions are given of the jaculus or common jerboa, and of the Arabian, Egyptian, and Siberian jerboas. A variety of this animal has lately been found in Canada by Major-general Davies, F. R. S. and L. S. who says it belongs to Schreber's genus of *Dipus*, and may be thus characterized: *DIPUS CANADENSIS palmis tetradactylis, plantis pentadactylis, caudâ annulatâ undique setosâ, corpore longiore*. The truth, however, seems to be, that it is only a variety, if indeed a variety, of the Siberian jerboa. The beautiful figure indeed given by General Davies of the Canadian jerboa differs in some respects from our figure of the Sibericus. Its ears lie flat and farther down the neck; its belly is not so large; its toes are longer; and it has no brush at the end of the tale; but the habits of the two animals seem to be the same. This will be apparent from the following extracts of the General's letter to the Linnean Society:

"The first I was so fortunate to catch was taken in a large field near the falls of Montmorenci, and by its having strayed too far from the skirts of the wood, allowed myself, with the assistance of three other gentlemen, to surround it, and after an hour's hard chase to get it unhurt, though not before it was thoroughly fatigued; which might in a great measure accelerate its death.

"During the time the animal remained in its usual vigour, its agility was incredible for so small a creature. It always took progressive leaps of from three to four, and sometimes of five yards, although seldom above 12 or 14 inches from the surface of the grass; but I have frequently observed others in shrubby places and in the woods, amongst plants, where they chiefly reside, leap considerably higher. When found in such places, it is

impossible to take them, from their wonderful agility, and their evading all pursuit by bounding into the thickest cover they can find."

Jerboa,
jillifree.

That the Canadian, as well as the Siberian Jerboa, sleeps through the winter, seems evident from a specimen having been found, towards the end of May, inclosed in a ball of clay, about the size of a cricket ball, nearly an inch in thickness, perfectly smooth within, and about twenty inches under ground. It was given to the General; who proceeds thus:

"How long it had been under ground it is impossible to say; but as I never could observe these animals in any parts of the country after the beginning of September, I conceive they lay themselves up some time in that month, or beginning of October, when the frost becomes sharp: nor did I ever see them again before the last week in May, or beginning of June. From their being enveloped in balls of clay, without any appearance of food, I conceive they sleep during the winter, and remain for that term without sustenance. As soon as I conveyed this specimen to my house, I deposited it, as it was, in a small chip box, in some cotton, waiting with great anxiety for its waking; but that not taking place at the season they generally appear, I kept it until I found it begin to smell: I then stuffed it, and preserved it in its torpid position. I am led to believe, its not recovering from that state arose from the heat of my room during the time it was in the box, a fire having been constantly burning in the stove, and which, in all probability, was too great for respiration. I am led to this conception from my experience of the snow bird of that country, which always expires in a few days (after being caught, although it feeds perfectly well) if exposed to the heat of a room with a fire or stove; but being nourished with snow, and kept in a cold room or passage, will live to the middle of summer."

JETTE, the border made round the stilts under a pier, in certain old bridges, being the same with starling; consisting of a strong framing of timber filled with stones, chalk, &c. to preserve the foundations of the piers from injury.

JILLIFREE is a town on the northern bank of the river Gambia, opposite to James's island, where the English had formerly a small fort. The kingdom of Barra, in which it is situated, produces great plenty of the necessaries of life; but the chief trade of the inhabitants is in salt, which they carry up the river in canoes; and, in return, bring down Indian corn, cotton cloths, elephants teeth, small quantities of Gold dust, &c. "The number of canoes and people constantly employed in this trade, make the king of Barra (says Mr Park) more formidable to Europeans than any other chieftain on the river, and have encouraged him to establish those exorbitant duties, which traders of all nations are obliged to pay at entry, amounting nearly to L. 20 on every vessel, great and small. These duties, or customs, are generally collected in person by the alkaid or governor of Jillifree, who is attended by a numerous train of noisy and troublesome dependants, who, by their frequent intercourse with the English, have acquired a smattering of our language, and beg for every thing which they fancy with such earnestness, that traders, in order to get quit of them, are frequently obliged to grant their requests. Lat. 13° 16'. Long. 16° 10' west from Greenwich.

Illuminati.

Object of the Illuminati.

ILLUMINATI is the name which was assumed by a secret society or order, founded, on the first of May 1776, by Dr Adam Weishaupt professor of canon law in the university of Ingolstadt. The real object of this order was, by clandestine arts, to overturn every government and every religion; to bring the sciences of civil life into contempt; and to reduce mankind to that imaginary state of Nature when they lived independent of each other on the spontaneous productions of the earth. Its avowed object, however, was very different. It professed to diffuse from secret societies, as from so many centres, the light of science over the world; to propagate the purest principles of virtue; and to re-inflate mankind in the happiness which they enjoyed during the golden age fabled by the poets. Such an object was well adapted to make a deep impression on the ingenuous minds of youth; and to young men alone Weishaupt at first addressed himself.

It will naturally occur to the reader, that the means of attaining this glorious object should have been made as public as possible; and that the veil of secrecy thrown over the proceedings of the order was calculated to excite suspicion, and to keep even young men of virtue and sagacity at a distance. In any other country than Germany secrecy might perhaps have had this effect; but various circumstances conspired there to make it operate with a powerful attraction.

Ever since free masonry had acquired such reputation throughout Europe, a multitude of petty secret societies had been formed in the universities of Germany, each having its lodge, its master, its mysteries, all modelled on those founded by masons coming from England and Scotland (A). Before the foundation of Weishaupt's order, these lodges, we believe, were in general harmless; or if they were productive of any evil, it was only by giving the youth of the universities a taste for secrecy and mysticism. Of this Weishaupt availed himself; and as soon as he had conceived the outlines of his plan, and digested part of his system, he initiated two of his own pupils, to whom he gave the names of AJAX and TIBERIUS, assuming that of SPARTACUS to himself. These two disciples soon vying with their master in impiety (for it will be seen by and bye that he was most impious), he judged them worthy of being admitted to his mysteries, and conferred on them the highest degree which he had as yet invented. He called them *Areopagites*, denominated this monstrous association, THE ORDER OF ILLUMINATI, OR ILLUMINEES, and installed himself GENERAL of the order.

When public report spread the news in Germany of this new order having been founded in the university of Ingolstadt by Weishaupt, it was generally supposed to be one of those little college-lodges which could not interest the adepts after they had finished their studies. Many even thought that Weishaupt, who was at that

time a sworn enemy to the Jesuits, had founded this lodge with no other view than to form a party for himself against these fathers, who after the suppression of their order had been continued in their offices of public teachers at the university of Ingolstadt; and this opinion the illuminees were at pains to propagate. His character, too, was at this time such as to remove every suspicion from the public mind. A seeming assiduity in his duty, and a great show of zeal and erudition in expounding the laws, easily misled people to believe that his whole time and talents were engrossed with the study of them; and if we are to credit his own account, Ingolstadt had never witnessed a professor so well calculated to add new lustre to its university.

This seems, indeed, to have been the general opinion as well as his own; for, some time after the foundation of his order, he applied himself with such diligence and apparent candour to the duties of his office, that he was chosen what Abbé Barruel's translator calls SUPERIOR of the university. This new dignity only added to his hypocrisy, and furnished him with fresh means of carrying on his dark designs. He converted his house into one of those boarding houses where young men, perpetually under the eye of their masters, are supposed to be better preserved than anywhere else from the dangers which threaten them at that age. He solicited fathers and mothers to entrust their children to his care; and, counterbalancing in secret the lessons which he was obliged to give in public, he sent home his pupils well disposed to continue the same career of seduction which he himself carried on at Ingolstadt. Atrociously impious, we see him (says M. Barruel), in the first year of his illuminism, aping the God of Christianity, and ordering *Ajax*, in the following terms, to propagate the doctrines of his new gospel: "Did not Christ send his apostles to preach his gospel to the universe? You that are my Peter, why should you remain idle at home? Go then and preach."

These preachers had yet received no particular designation; for when his first adepts were initiated, he was far from having completed the code of his order. He knew that years and experience were necessary to perfect that gradual system of initiations and trials which, according to the plan he had conceived, his novices were to undergo; but he could not endure the idea of sacrificing years to mere theoretic projects; and he flattered himself with the hopes of supplying the deficiencies of his incomplete code by provisional regulations and private instructions, and of acquiring associates who would receive his new gospel implicitly, and cooperate with him in all his views.

At length, however, the code was completed, and the sect divided into two grand classes; and each of these again subdivided into lesser degrees, proportionate to the progress of the adepts.

The

(A) Such, we are sorry to say, is the case still. In a letter, dated the 10th of May 1799, which we received from a gentleman of learning and honour then residing in Upper Saxony, is the following account of the university of Jena: "This university contains from two to three thousand students, who are almost all republicans, and go about the country in republican uniforms. They are all formed into clubs or *secret societies*; and the quarrel of one member of a club is taken up by all. The consequence is, that the number of duels among the different clubs is inconceivable. The weapon is generally the sabre, and the duel often ends in the death of one of the combatants." Yet gentlemen of Great Britain send their sons to Germany to be educated!

⁴ **Illuminati.** "The first class is that of PREPARATION. It contains four degrees, viz. those of *Novice*, of *Minerval*, of *Minor Illuminee*, or *Illuminatus Minor*, and of *Major Illuminee*, or *Illuminatus Major*. To this class belong likewise some intermediary degrees, borrowed from freemasonry, as means of propagation. Of the masonic degrees, the code of the illuminati admits the first three without any alteration; but it adapts more particularly to the views of the sect the degree of *Scotch Knight*, and styles it the degree of *Directing Illuminee*, or *Illuminatus dirigens*.

⁵ **The Mysteries.** The second class is that of the MYSTERIES, which are subdivided into the *lesser* and *greater mysteries*. The lesser comprehend the priesthood, and administration of the sect, or the degrees of *priests*, and of *regents or princes*.

In the *greater mysteries* are comprehended the two degrees of *Magus* or philosopher, and of the *Man-king*. The *elect* of the latter compose the *council and degree of Arcopagites*.

"In all these classes, and in every degree (says the Abbé Barruel), there is an office of the utmost consequence, and which is common to all the brethren. It is that which is occupied by him who is known in the code by the appellation of *Recruiter*, or *Brother Insinuator*. This (continues our author) is not a term of my invention: it is really to be found in the code, and is the denomination of that illuminee, whose employment is to entice members into the sect."

⁶ **The recruiter.** As the whole strength of the order depended upon the vigilant and successful exercise of this office, some brethren were carefully instructed for it, who might afterwards visit the different towns, provinces, and kingdoms, in order to propagate the doctrines of illuminism. Weishaupt proposed to select as his apostles either weak men, who would implicitly obey his orders, or men of abilities, who would improve the office by artifices of their own. It was, however, a duty which every brother was obliged to exercise once or twice in his life, under the penalty of being for ever condemned to the lower degrees.

To stimulate the ardour of the brother insinuator, he was appointed superior over every novice whom he should convert. To assist his judgment, he was instructed in three important points concerning the description of men whom he ought to select for conversion, the means which he ought to employ for enticing them to enter the order, and the arts which he ought to study to form their character.

⁷ **To pry into the characters of all men.** To enable the recruiter to determine whom he ought to select for conversion, he was to insinuate himself into all companies; he was to pry into the character of all whom he should meet with, whether friends, relations, strangers, or enemies; he was to write down all his remarks regularly every day; to point out their strong and weak sides, their passions and prejudices, their intinacies, their interests, and their fortune. This journal was to be transmitted twice every month to the superiors; by which means the order would learn who were friendly or hostile to their views, and who were the individuals to whom they ought to direct their arts of seduction (B).

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The persons to be excluded were all such as would expose the order to suspicion or reproach. All indiscreet talkers, all who were proved violent, and difficult to be managed, all addicted to drunkenness, and all Pagans, Jews, and Jesuits, were to be rejected. As the patronage of princes would tend much to enrich and strengthen the society, it was agreed to admit them to the inferior degrees, but they were never to be initiated into the grand mysteries; they were never to rise beyond the degree of Scotch knight.

⁸ **Persons proper for the order.** The persons to be selected were young men of all stations, from eighteen to thirty; but particularly those whose education was not completed, and consequently whose habits were not formed. "Seek me out (says Weishaupt in his directions to the insinuator) the dexterous and dashing youths. We must have adepts who are insinuating, intriguing, full of resource, bold and enterprising; they must also be flexible and tractable, obedient, docile, and soeiable." In another place he says, "Above all things pay attention to the figure, and select the well made men and handsome young fellows. They are generally of engaging manners and nice feelings. When properly formed, they are the best adapted for negotiations; for first appearances prepossess in their favour. It is true, they have not the depth that men of more gloomy countenances often have. *They are not the persons to be entrusted with a revolt, or the care of stirring up the people*; but it is for that very reason we must know how to choose our agents. I am particularly fond of those men whose very soul is painted in their eyes, whose foreheads are high, and whose countenances are open. Above all, examine well the eyes, for they are the very mirrors of the heart and soul. Observe the look, the gait, the voice. Every external appearance leads us to distinguish those who are fit for our school."

Though young men were preferred, yet persons of all ages were to be admitted if their character accorded with the principles of the order. The insinuator was desired to seek out those who were distinguished by their power, riches, or learning. "Spare no pains (says Weishaupt), spare nothing in the acquisition of such adepts. If heaven refuse its succour, conjure hell.

Fleere si nequeas superos, Acheronta moveta."

Persons were to be singled out from those professions which give men influence over others, or put them in the most favourable situation for disseminating any peculiar opinions. With this view, schoolmasters, and superintendants of ecclesiastic seminaries, were to be sought after with much care. Booksellers, post-masters, and the secretaries of post-offices, were also to be selected. Those professions which accustomed men to speak and argue, as that of counsellors and attorneys, and even physicians, were also to be courted. "They are worth having (says Weishaupt), but they are sometimes real devils, so difficult are they to be led; they are, however, worth having when they can be gained over." Every exertion was to be made to gain the officers of a prince, whether presiding over provinces or attending him in his councils. "He that has done this, has done more than if he had engaged the prince himself."

5 E

There

(B) As a specimen of the journals kept by the insinulators, and of the characters which the illuminees selected for

Illuminati.

There was also another description of men of whom Weishaupt very wisely judged that they would be admirably fitted for the diffusion of his doctrines. These were the disappointed and dissatisfied. "Select those in particular (says he) who have met with misfortunes, not from accidents, but from some injustice; that is to say, in other words, the discontented; for such men are to be called into the bosom of illuminism as into their proper asylum.

10
And their characters transmitted to the superiors.

When the insinuator has made choice of his victim, he is required to draw from his diary a view of his character, opinions, principles, and connections. This he is to transmit to the superiors for their examination, and that they may compare it with the diaries which they have already received, perhaps from different insinulators. When the choice of this insinuator is approved, the superiors determine which of the insinulators will be best qualified to perform the task of seducing their candidate.

Two different methods were recommended; one of which was to be employed in enticing men who were somewhat advanced in life or distinguished by science; the other was to be used in seducing young men whose character was not formed.

11
Proper methods of seducing men of knowledge,

With men of knowledge, who had already imbibed the principles of modern philosophism (for no true philosophers were to be attempted), the insinuator was to assume the character of a philosopher well acquainted with the mysteries of ancient times. He was to descant upon the importance of the secret doctrines transmitted by tradition, to quote the gymnosophists of India, the priests of Isis in Egypt, and those of Eleusis, with the Pythagorean school in Greece. He was to learn by heart certain passages from Isocrates, Cicero, and Seneca, that he might have them ready upon all occasions. He was to throw out hints, that these secret doctrines explained the difficult questions concerning the origin and order of the universe, the Providence of God, the nature of the soul, its immortality and future destination; he was to inspire them with the belief that the knowledge of these things would render life more agreeable and pain more supportable, and would enlarge their ideas of the majesty of God: he was then to declare that he had been initiated into these mysteries. If the candidate expressed any curiosity to be made acquainted

with them, the insinuator was first to ascertain his opinions upon some leading points, by proposing to him to write a dissertation upon certain questions. Should the answers not please the insinuator, he was to relinquish his prey; but should they be satisfactory, the candidate was to be admitted to the first degree.

Illuminati.

When the selected victim was young, and had not imbibed any of those opinions which corresponded with the principles of the sect, a different method was to be followed. "Let your first care (says the legislator to his insinulators) be to gain the affection, the confidence, and the esteem of those whom you are to entice into the order. Let your whole conduct be such, that they shall surmise something more in you than you wish to shew; hint that you belong to some secret and powerful society; excite by degrees, and not at once, a wish in your candidate to belong to a similar society. Certain arguments and certain books, which the insinuator must have, will greatly contribute to raise such a wish; such, for example, are those which treat of the union and strength of associations."

12
And young men,

Every insinuator must be provided with books of this sort. But that their success might not depend solely upon books, Weishaupt gave to his disciples a specimen of the artifices which they might employ. The insinuator might begin by observing, that a child in the cradle, abandoned to itself, is entirely helpless; and that it is by the assistance of others that it acquires strength; and that princes owe their greatness and their power to the union of their subjects. Then the insinuator might touch on the importance of knowing mankind, and the arts of governing them; that one man of parts might easily lead hundreds, even thousands, if he but knew his advantages. He was next to dwell upon the defects of civil society; to mention how little relief a man can obtain even from his best friends; and how very necessary it is for individuals to support one another in these days: to add, that men would triumph even over heaven were they but united. He was to adduce as examples, the influence of the freemasons and of the Jesuits. He was to assert, that all the great events which take place in the world depend upon hidden causes, which these societies powerfully influence. He was to awake in the breast of his pupil the desire of reigning in secret; of preparing

for propagating their principles, we shall give the character of Zwack, denominated *Cato*, as it is described in the tablet of his insinuator Ajax (Massenhausen).

"Francis Xaverius Zwack was son of Philip Zwack, commissary of the *Chambre de Comptes*, and was born at Ratisbon; at the time of his initiation (29th May 1776) he was twenty years of age, and had finished his college education.

"He was then about five feet high; his person emaciated with debauchery; his constitution bordering on melancholy; his eyes of a dirty grey, weak and languishing; his complexion pale and fallow; his health weak, and much hurt by frequent disorders; his nose long, crooked and hooked; his hair light brown; gait precipitate; his eyes always cast towards the ground; under the nose, and on each side of the mouth, a mole.

"His heart tender and philanthropic in an extraordinary degree; but stoic when in a melancholy mood; otherwise a true friend, circumspect, reserved, extremely secret; often speaking advantageously of himself; envious of other people's perfections; voluptuous; endeavouring to improve himself; little calculated for numerous assemblies; choleric and violent, but easily appeased; willingly giving his private opinions when one has the precaution to praise him, though contradicting him; a lover of novelties. On religion and conscience widely differing from the received ideas; and thinking precisely as he ought, to become a good member of the order.

"His predominant passions are, pride, love of glory, probity; he is easily provoked; has an extraordinary propensity for mysteries; a perpetual custom of speaking of himself and of his own perfections; he is also a perfect master in the arts of dissimulation; a proper person to be received into the order, as applying himself particularly to the study of the human heart." Such is the character of the beloved disciple of Weishaupt, the incomparable *Cato*, and a leader of the sect of the illuminees!

illuminati. ring in his closet a new constitution for the world; and of governing those who think they govern others.

13
Into the
noviciate.

After these, or other artifices of the same kind, have been employed, if the candidate be inspired with an ardour to be initiated, and give satisfactory answers to the questions proposed to him, he is immediately admitted a novice. But should he reject all means of seduction, let him take heed to himself; "for the vengeance of secret societies is not a common vengeance; it is the hidden fire of wrath. It is irreconcilable; and scarcely ever does it cease the pursuit of its victims until it has seen them immolated."

14
Period of
the noviciate.

The period of the noviciate varied according to the age of the new convert to illuminism. At first it continued three years for those under 18 years of age, two years for those between 18 and 24, and one year for those who were near 30; but it was afterwards shortened,

The novice was not acquainted with any of the order except his insinuator, under whose direction he remained during his noviciate. The first lessons which he was taught respected the inviolable nature of the secrecy which every illuminee was obliged to observe. He was told that silence and secrecy were the very soul of the order; that ingenuousness was a virtue only with respect to his superiors; and that distrust and reserve were fundamental principles. He was enjoined never to speak of any circumstance relating to the order, concerning his own admission, or the degree which he had received, not even before brethren, without the strongest necessity; and was required to sign a declaration to this purpose.

15
Dictionary,
geography,
calendar,
and cypher
of the or-
der.

The novice was next taught the dictionary of the order, its geography, calendar, and cypher. To prevent the possibility of discovery, every illuminee received a new name, which was characteristic of his dispositions, or of the services which were expected of him. Thus Weishaupt, as we have observed, was called *Spartacus*, because he pretended to wage war against those oppressors who had reduced mankind to slavery; and Zwack, as we have seen, was named *Cato*, because he had written a dissertation in favour of suicide, and had once determined to commit that crime.

According to the new geography of the order, Bavaria was called *Achaia*; Munich was called *Athens*; Vienna was named *Rome*; Wurtzburg was denominated *Carthage*; and Ingolstadt, the fountain of the order, was called *Ephesus*, and by the profound adepts *Eleusis*. The novice had also to learn the Persian calendar, which the order had adopted. Their era began A. D. 630. The months received new names: May was called *Adarpabascht*; June, *Chardad*; July, *Thermeh*; August, *Merdedmeh*; and so on. The cypher consisted of numbers which corresponded to the letters of the alphabet, in this order *a, b, c, d*, answering to the numbers 12, 11, 10, 9.

The novice had next to study the statutes of the illuminees, which he was assured contained nothing injurious to the state, to religion, or to good morals. He was next desired to apply himself to acquire the morality of the order; which he was to do, not by reading the gospels, but by perusing Epictetus, Seneca, and Antoninus, and by studying the works of the modern sophists Weiland, Meiners, and Helvetius, &c. The study of man was also recommended as the most interest-

ing of all the sciences. He was taught this study not merely as a science, but as an art. A model of a journal was given him, and he was required to insert in it observations upon the character of every person that he happened to meet with. To quicken his diligence, the insinuator occasionally examined his journal. In the mean time, the insinuator was watching him as a sentinel, and noting down regularly observations upon the defects and merits of his pupil, which he always sent to his superiors.

16
Novice o-
bliged to
draw his
own cha-
racter.

The great object of the insinuator was to entangle the novice, and to bind him indissolubly to the order. With this view he required the novice to draw a faithful picture of himself, under the pretence that he would thus know himself better. He desired him to write down his name, his age, his country, his residence, and his employment; to give a list of the books in his library; to state his revenue; to enumerate his friends and enemies, and the cause of his enmities. He was also to give a similar account of his father and mother, his brothers and sisters, and to be very careful in pointing out their passions and prejudices, their strong and weak sides.

In the mean time, the insinuator was occupied in drawing up a new statement of every thing he had been able to discover of the character and conduct of the novice. This statement was transmitted to the superiors, compared with the former. If the novice was approved, he was then admitted to the second degree, upon his answering, in a satisfactory manner, 24 grand questions, which might enable the order to judge of his principles and the credit to which he was entitled, and would fix him down by stronger ties to the authority of the superiors. The detestable principles of the illuminees now begin to appear, as will be evident from the following questions which we have selected:

17
Power of
life and
death
claimed by
the society.

Have you seriously reflected on the importance of the step you take, in binding yourself by engagements that are unknown to you? Should you ever discover in the order any thing wicked or unjust to be done, what part would you take? Do you, moreover, grant the power of life and death to our order or society? Are you disposed, upon all occasions, to give the preference to men of our order over all other men? Do you subject yourself to a blind obedience, without any restriction whatsoever?

The novice having thus surrendered his conscience, his will, and his life, to the devotion of the conspirators, and thus subscribed, with his own hand, and confirmed by his oath, a resolution to become the most abject slave, was now deemed qualified to ascend to the second degree, called *Minerval*.

18
Admission
to the de-
gree of Mi-
nerval.

In the dead hour of midnight he was conducted to a retired apartment, where two of the order were waiting to receive him. The superior, or his delegate, appeared standing in a severe and threatening posture; he held a glimmering lamp in his hand, and a naked sword lay before him. The novice was asked, whether he still persisted in his intention of adhering to the order? Upon answering in the affirmative, he was ordered into a dark room, there to meditate in silence on his resolution. On his return, he was strictly and repeatedly questioned if he was determined to give implicit obedience to all the laws of the order? The insinuator became security for his pupil, and then requested for him the protection of the order, which the superior granted with great solemnity,

Illuminati. nity, protesting that nothing would be found there hurtful to religion, to morals, or to the state. Having thus said, the superior takes up the naked sword, and pointing it at the heart of the novice, threatens him with the fatal consequences of betraying the secrets of the order. The novice again takes an oath, by which he binds himself, in the most unlimited manner, to save the order with his life, honour, and estate, and to observe an inviolable obedience and fidelity to all his superiors. He is then admitted a Minerval, and henceforth is allowed to attend the academy of the sect.

19
Minerval
academy;

The Minerval academy was composed of 10, 12, or 15 Minervals, and placed under the direction of a major Illuminee. It met twice every month in an inner apartment, separated from the other rooms of the mansion by an antichamber; the door of which was to be shut with care during the meeting, and strongly secured by bolts. At the commencement of every meeting, the president read and commented upon some select passages of the Bible, Seneca, Epictetus, Marcus Aurelius, or Confucius; evidently with a view of diminishing the reverence for the sacred writings, by thus placing them on a level with the heathen moralists. Then each brother was asked what books he had read since last meeting, what observations he had made, and what services he had performed for promoting the success of the order?

20
Its library.

To each Minerval academy a library belonged. This was formed by the contributions of the brethren, by presents of books, and by another method very extraordinary. All Illuminees acting as librarians, or keepers of archives, were admonished to *steal* such books or manuscripts as might be useful to the order. At one time, sending a list of the books which he wished to be embezzled from the library of the Carmes, Weishaupt says, "All these would be of much greater use if they were in our hands. What do those rascals do with all these books?"

Every brother at his admission was required to declare to what art or science he meant chiefly to apply; and it was expected that he should afterwards every year give an account of the discoveries or improvements which he had made. All the other brethren who were occupied in the same studies, were desired to give him every possible assistance. Thus a kind of academy was formed, to which those who could not serve it by their talents might give pecuniary contributions. That this academy might have the appearance of a literary society, prizes were annually distributed; the best discourse was published, and the profits sent to the coffers of the order.

Every month the president was to take a review of the faults which he had observed in his pupils, and examine them concerning those which they might have been conscious of in themselves; and it would be an unpardonable neglect, say the statutes, should any pupil pretend that, during the space of a whole month, he had remarked nothing reprehensible.

It is impossible to read these rules without admiring them. Were men but half as anxious, attentive, and careful, to render themselves good citizens and good men, as these men were to render themselves successful conspirators, what a blessed world should we see!

21
Admission
to the de-
gree of mi-
nor illumine-
e.

The Minerval was rigorously scrutinized, whether he was ready to submit to every torture, or even to com-

mit suicide, rather than give any information against the order. Suicide was reckoned not only innocent, but honourable, and was also represented as a peculiar species of voluptuousness. In order to discover the sentiments of the Minervals upon this subject, they were required to write a dissertation upon the character and death of Cato, or any similar subject. They were also desired to discuss the favourite doctrine of Weishaupt, that *the end sanctifies the means*; a principle of the most pernicious tendency, which would render calumny, assassination, sedition, and treason, laudable and excellent. Next, they were called upon to compose a dissertation, by which their opinions concerning kings and priests might be ascertained. If they performed all these tasks with the spirit of an infidel, and the desperate firmness of a conspirator, they were then judged worthy of being promoted to the degree of minor illuminee.

The minor illuminees held meetings similar to those of the Minerval academy. It was necessary that the president should be one who was raised to the degree of priest, and initiated in the mysteries; but he was required to persuade his pupils, that beyond the degree which he had attained there were no mysteries to be disclosed. The minor illuminees were to be so trained, that they might look upon themselves as the founders of the order; that by this powerful motive they might be animated to diligence and exertion. With this view, hints were scattered rather than precepts enjoined. It was insinuated, that the world was not so delightful as it ought; that the happiness for which man was made is prevented by the misfortunes of some, and the crimes of others; that the wicked have power over the good; that partial insurrection is useless; and that peace, contentment, and safety, might be easily obtained by means drawn from the greatest degree of force of which human nature is capable. Such views, it is added, actuating a secret society, would not only be innocent, but most worthy of the wise and well-disposed.

22
Mi- or il-
luminees
trained for
the degree
of

Weishaupt had formed, with peculiar care, a code for this degree, which was intitled, *Instructions for forming useful Labourers in Illuminism*. These instructions discover an astonishing knowledge of human nature, and are drawn up with a degree of systematic coolness which perhaps no conspirator before him ever exhibited. He lays down rules, by which the character of almost any person may be ascertained. He recommends to the minor illuminees, to attend to the conduct of any person entrusted to their care, at two periods; when he is tempted to be what he ought not to be, and when, removed from the influence of every external temptation, he follows the dictates of his inclination. They were to study the peculiar habits and ruling passions of each; to kindle his ardour by descanting on the dignity of the order, and the utility of its labours; to infuse a spirit of observation, by asking questions, and applauding the wisdom of the answers; to correct the failings of their pupil, by speaking of them as if they were not his, and thus making him judge in his own cause; to instruct and advise, not by tedious declamation, but by sometimes dropping a few words to the purpose, when the mind should be in a proper state to receive them. Above all, they were directed to avail themselves of those moments when they observed a pupil discontented with the world. "It is then (says Weishaupt) you must press the swelling heart, stimulate the sensibility,

and

illuminati. and demonstrate how necessary secret societies are for the attainment of a better order of things."

²³ Scotch no. vice. Having passed with applause through the states of probation already described, the minor illuminee is promoted to the rank of major illuminee, or Scotch novice. As major illuminee, he is encompassed with more rigid chains; and as Scotch novice, he is dispatched as a missionary into masonic lodges, to convert the brethren to illuminism.

The candidate for this degree is strictly examined, in order to discover what opinions he now entertains concerning the object of the society; the motives that prompted him to join it; whether he is disposed still to co-operate with the rest of the brethren in accomplishing the grand object; and whether he be a member of any other society; and what are the duties which it requires.

The fertile genius of Weishaupt is not exhausted; he has still in reserve artifices more profound, and bonds more powerful; his resources keep pace with the progress of his schemes. He now lays a snare for his pupils, from which he hopes none can escape, and therefore he flatters himself they are his for ever. He demands of every candidate for higher degrees, to write, as a proof of confidence, a minute and faithful account of his whole life, without any reserve or dissimulation. Reserve or dissimulation would indeed be vain; for the most secret circumstances of his life are already well known to the adepts, by means of innumerable spies, who, by the appointment of the superiors, have, unknown to him, been watching and scrutinizing all his actions and words, his temper, passions, and opinions.

Now is presented to the candidate the code of the brother scrutator, called by the order the *nosce te ipsum* (know thyself). This is a catechism, containing from a thousand to fifteen hundred questions, concerning his person, his health, his education, his opinions, his inclinations, his habits, his passions, his prejudices, and even his weaknesses. Questions are also proposed respecting his acquaintances, his relations, friends, and enemies. The candidate is required to enumerate his favourite colours, to describe his language, the nature of his conversation, his gait and gestures. Nothing, in short, is omitted that can tend to distinguish his character as an individual, or as a member of society. Upon many qualities in his character, thirty, forty, or sometimes near a hundred questions are proposed. The following specimen will enable the reader to judge what astonishing care Weishaupt employed to discriminate characters.

Is his *gait* slow, quick, or firm? Are his steps long, short, dragging, lazy, or skipping? Is his *language* regular, disorderly, or interrupted? In speaking, does he agitate his hands, his head, or his body with vivacity? Does he close upon the person he is speaking to? Does he hold him by the arm, clothes, or button-hole? Is he a great talker, or is he taciturn? If so, why? Is it through prudence, ignorance, respect, or sloth? &c. Concerning his *education*, he is questioned to whom does he owe it? Has he always been under the eyes of his parents? How has he been brought up? Has he any esteem for his masters? Has he travelled, and in what countries?

By these questions his temper and dispositions might be accurately known. His leading passions would be

illuminati. discovered by the following queries: "When he finds himself with different parties, which does he adopt; the strongest or the weakest; the wittiest or the most stupid? Or does he form a third? Is he constant and firm in spite of all obstacles? How is he to be gained? by praise, by flattery, or low courtship; by women, money, or the entreaties of his friends? Does he love satire; and on what does he exercise that talent; on religion, hypocrisy, intolerance, government, ministers, monks?" &c.

All these questions are to be answered and illustrated by facts. It is necessary to observe that the scrutators also give in written answers to all these questions. When the candidate has thus given a minute history of his life, and revealed all his secrets, his foibles, his errors, his vices, and his crimes, Weishaupt triumphantly exclaims, "Now I hold him; I defy him to hurt us; if he should wish to betray us, we have also his secrets."

The adept is next introduced into a dark apartment, where he solemnly swears to keep secret whatever he may learn from the order. He then delivers up the history of his life, sealed, when it is read to the lodge, and compared with the character drawn of him by the brother scrutators. A corner of the veil is now lifted up, still, however, with extreme caution. Nothing appears palpable but the purest principles and most generous designs. At the same time many things are darkly suggested, which are incompatible with purity and generosity; for while the utmost care is employed to deceive the understanding, nothing is neglected that can tend secretly to corrupt the heart. A number of questions are asked; the evident intention of which is to make the adept discontented with the present moral government of the world, and to excite the desire of attempting a great revolution. After answering these questions, the secretary opens the code of the lodge; and having informed the young illuminee that the object of the order is to diffuse the pure truth, and to make virtue triumph, he proceeds to show that this is to be accomplished by freeing men from their prejudices, and enlightening their understandings. "To attain this, (continues the secretary), we must trace the origin of all sciences, we must reward oppressed talents, we must undertake the education of youth; and, forming an indissoluble league among the most powerful geniuses, we must boldly, though with prudence, combat superstition, incredulity, and folly; and at length form our people to true, just, and uniform principles on all subjects." The secretary adds, that in attempting to divest vice of its power, that the virtuous may be rewarded even in this world, the order is counteracted by *princes and priests, and the political constitutions of nations*; that, however, it was not intended to excite revolutions and oppose force by force, but merely to bind the hands of the protectors of disorder, and to govern without appearing to command; that the powers of the earth must be encompassed with a legion of indefatigable men, all directing their labours towards the improvement of human nature. Were there but a certain number of such men in every country, each might form two others. "Let these (says he) only be united, and nothing will be impossible to our order." All this is very specious; it is well contrived to fascinate the imagination of the young, and the heart of

²⁴ Candidates for higher degrees submit to new trials.

Illuminati. the generous and benevolent, while, under all this pretended regard to virtue and to the happiness of mankind, is concealed a most formidable conspiracy against the peace of the world.

After this address is delivered, the major illuminee is presented with the codes of the insinuator and scrutator; for he must now inspect the pupils of the insinulators, and must exercise the office of scrutator while presiding over the Minerval academies.

²⁵
The degree of Scotch knight.

The next degree, which is that of Scotch knight, is both intermediate and stationary. It is stationary for those who are not sufficiently imbued with the principles of the order, and intermediate for those who have imbibed the true spirit of illuminism. The Scotch knights were appointed the directors of all the preparatory degrees, and to watch over the interests of the order within their district. They were to study plans for increasing the revenues of the order, and to endeavour to promote to public offices of confidence, of power and wealth, as many of the adepts as possible; and to strive to acquire an absolute sway in the masonic lodges. They were to procure the management of the masonic funds; and while they were to persuade the brethren that these were expended according to their own orders, they were to employ them for promoting the views of the order. Thus one office of the Scotch knights was to embezzle the money that was entrusted to them, in order to diffuse truth, and to make virtue triumph.

After passing with applause through this long and tedious probation, the adept is introduced to the class of the mysteries. He is not yet, however, made acquainted with the whole secrets of the society; he must still submit to new trials; his curiosity must be farther excited, his imagination must be kept longer upon the stretch, and his principles of depravity be rendered more violent and inveterate before the veil be entirely withdrawn, which will discover to him Weishaupt and his infernal crew, plotting the destruction of the laws, sciences, and religion of mankind. The degree of epopt or priest, to which the adept was next raised, opened to view, however, so great a part of the mysteries, that the reader will be fully prepared to expect the secrets which remain to be unfolded in the other degrees.

²⁶
Preparations for the priesthood.

Before being admitted to the degree of epopt, the adept was required to give a written answer to ten preliminary questions. The insinuations against the established order of the world, which had formerly been slightly mentioned, increase now to an indirect proposal to attempt a complete revolution. The candidate is asked, whether he thinks the world has arrived at that happy state which was intended by nature? Whether civil associations and religion attain the ends for which they were designed? Whether the sciences are conducive to real happiness? or whether they are not merely the offspring of the unnatural state in which men live, and the crude inventions of crazy brains? It is then proposed as a question, whether there did not in ancient times exist an order of things more simple and happy? What are the best means for restoring mankind to that state of felicity? Should it be by public measures, by violent revolutions, or by any means that would ensure success? Would it not be proper, with this view, to preach to mankind a religion more per-

fect, and a philosophy more elevated? And, in the mean time, is it not advisable to disseminate the truth in secret societies?

Should the answers given to these questions accord with the sentiments of the order, on the day fixed for the initiation, the candidate is blindfolded, and, along with his introducer, is put into a carriage, the windows of which are darkened. After many windings and turnings, which it would be impossible for the adept to trace back, he is conducted to the porch of the temple of the mysteries. His guide strips him of the masonic insignia which he wore as a knight, removes the bandage from his eyes, and presents him with a drawn sword; and then having strictly enjoined him not to advance a step till he is called, leaves him to his meditations. At length he hears a voice exclaiming, "Come, enter, unhappy fugitive; the fathers wait for you; enter, and shut the door after you." He advances into the temple, where he sees a throne with a rich canopy rising above it, and before it, lying upon a table, a crown, a sceptre, a sword, some pieces of gold, and precious jewels, interlaid with chains. At the foot of the table, on a scarlet cushion, lie a white robe, a girdle, and the simple ornaments of the sacerdotal order. The candidate is required to make his choice of the attributes of royalty, or of the white robe. If he choose the white robe, which he knows it is expected he should do, the hierophant, or instructor, thus addresses him: "Health and happiness to your great and noble soul. Such was the choice we expected from you. But stop; it is not permitted you to invest yourself with that robe, until you have heard to what we now destine you." The candidate is then ordered to sit down; the book of the mysteries is opened, and the whole brethren listen in silence to the voice of the hierophant.

²⁷
Instructions previous to admission.

The exordium is long and pompous; much artifice is concealed in it, and much eloquence displayed. It expatiates on the sublime and generous views of the society; evidently with the desire of lulling asleep the suspicion of the candidate, of exciting him to admiration, and of inspiring him with enthusiasm. The hierophant then proceeds to unveil the mysteries. He launches out into a splendid description of the original state of mankind; when health was their ordinary state, when meat, and drink, and shelter, were their only wants. At that period (says he) men enjoyed the most inestimable blessings, *equality and liberty*; they enjoyed them to their utmost extent: but when the wandering life ceased, and property started into existence; when arts and sciences began to flourish; when a distinction of ranks and civil associations were established, "liberty was ruined in its foundation, and equality disappeared. The world then ceased to be a great family, to be a single empire; the great bond of nature was rent asunder." Wants now increased, and the weak imprudently submitted to the wise or the strong, that they might be protected. As the submission of one person to another arises from wants, it ceases when the wants no longer exist. Thus the power of a father is at an end when the child has acquired his strength. Every man, having attained to years of discretion, may govern himself; when a whole nation, therefore, is arrived at that period, there can exist no farther plea for keeping it in wardship.

Such

Illuminati. Such a state as that of civil society, is then represented as incompatible with the practice of virtue. "With the division of the globe, and of its states, benevolence (says the hierophant) was restrained within certain limits, beyond which it could no longer be extended. Patriotism was deemed a virtue; and he was styled a patriot who, partial towards his countrymen, and unjust to others, was blind to the merits of strangers, and believed the very vices of his own country to be perfections. We really beheld (continues he) patriotism generating localism, the confined spirit of families, and even egoism. Diminish, reject that love of country, and mankind will once more learn to know and love each other as men. Partiality being cast aside, a union of hearts will once more appear, which will expand itself over the globe."

These unphilosophical declamations, enthusiastically pronounced, at length make the profelyte exclaim, in unison with his master, "Are such then the consequences of the institution of states, and of civil society? O folly! Oh people! that you did not foresee the fate that awaited you; that you should yourselves have seconded your despots in degrading human nature to servitude, and even to the condition of the brute!"

Having wrought up the profelyte to this pitch of frenzy, and enumerated all the evils which, according to Weishaupt, arise from political association, the hierophant comes to reveal the means by which the grievances of the human race may be redressed. "Providence (he says) has transmitted the means to us of secretly meditating, and at length operating, the salvation of human kind. These means are the secret schools of philosophy. These schools have been in all ages the archives of nature, and of the rights of man. These schools shall one day retrieve the fall of human nature, and PRINCES AND NATIONS SHALL DISAPPEAR FROM THE FACE OF THE EARTH; and that without any violence. Human nature shall form one great family, and the earth shall become the habitation of the man of reason. Reason shall be the only book of laws, the sole code of man. This is one of our grand mysteries. Attend to the demonstration of it; and learn how it has been transmitted down to us."

This pretended demonstration makes part of the same sophistical harangue; and consists in panegyrics on the dignity of human nature; in a baseless morality; and in a scandalous perversion of the Christian Scriptures, with a blasphemous account of the ministry of the Saviour of the world.

"What strange blindness (continues the hierophant) can have induced men to imagine, that human nature was always to be governed as it has hitherto been? Where is the being who has condemned men, the best, the wisest, and the most enlightened men, to perpetual slavery? Why should human nature be bereft of its most perfect attribute, that of governing itself? Why are those persons to be always led who are capable of conducting themselves? Is it then impossible for mankind, or at least the greater part of them, to come to majority? Are we then fallen so low as not even to feel our chains, as to hug them, and not cherish the flattering hope of being able to break them, and recover our liberty? No; let us own that it is not impossible to attain UNIVERSAL INDEPENDENCE."

The principal means which Weishaupt offers to his

adepts for the conquest of this land of promise, is to diminish the wants of the people; and accordingly the code denounces eternal war with every species of commerce. Hence the hierophant proceeds to inform the candidate, that he who wishes to subject nations to his yoke, need but to create wants, which he alone can satisfy. "Confer (says he) upon the mercantile tribe some rank or some authority in the government, and you will have created perhaps the most formidable, the most despotic of all powers. He, on the contrary, who wishes to render mankind free, teaches them how to refrain from the acquisition of things which they cannot afford: he enlightens them, he infuses into them bold and inflexible manners. If you cannot diffuse, at the same instant, this degree of light among all men, at least begin by enlightening yourself, and by rendering yourself better. The mode of diffusing universal light is, not to proclaim it at once to the whole world, but to begin with yourself; then turn to your next neighbour: you too can enlighten a third and a fourth: let these in the same manner extend and multiply the number of the children of light, until numbers and force shall throw power into your hands. You will soon acquire sufficient force to bind the hands of your opponents, to subjugate them, and to stifle wickedness in the embryo;" i. e. you will soon be able to stifle every principle of law, of government, of civil or political society, whose very institution, in the eyes of an illuminee, is the germ of all the vices and misfortunes of human nature.

The hierophant, continuing to insist on the necessity of enlightening the people to operate the grand revolution, seems to be apprehensive that the candidate may not yet clearly conceive the real plan of this revolution, which is in future to be the sole object of all his instructions. Let your instructions and lights be universally diffused; so shall you render mutual security universal; and security and instruction will enable us to live without prince or government. The instruction which is to accomplish this great end, is instruction in morality, and morality alone; for "true morality is nothing else than the art of teaching men to shake off their wardship, to attain the age of manhood; and thus to need neither princes nor governments. The morality which is to perform this miracle, is not a morality of vain subtleties. It is not that morality which, degrading man, renders him careless of the goods of this world, forbids him the enjoyment of the innocent pleasures of life, and inspires him with the hatred of his neighbour. Above all, it must not be that morality which, adding to the miseries of the miserable, throws them into a state of pusillanimity and despair, by the threats of hell and the fear of devils. It must be a divine doctrine, such as Jesus taught to his disciples, and of which he gave the real interpretation in his secret conferences."

The impious hierophant then proceeds, with matchless blasphemy, to represent the Redeemer of mankind as teaching, like the Grecian sophists, an esoteric and an esoteric doctrine. He describes him as the grand master of the illuminees; and affirms, that the object of his secret, which is lost to the world in general, has been preserved in their mysteries. It was "to re-instate mankind in their ORIGINAL EQUALITY and LIBERTY, and to prepare the means. This explains in what

Illuminati.
28
The illuminees enemies to commerce.

29
Their morality;

30
And blasphemies of Christ.

¹ *Illuminati.* what sense Christ was the *Saviour and Redeemer of the world.* The doctrine of original sin, of the fall of man, and of his regeneration, can now be understood. The state of pure nature, of fallen or corrupt nature, and the state of grace, will no longer be a problem. Mankind, in quitting their state of *original liberty, fell* from the state of nature, and *lost their dignity.* In their civil society, under their governments, they no longer live in the state of *pure nature*, but in that of *fallen and corrupt nature.* If the moderating of their passions, and the diminution of their wants, reinstate them in their primitive dignity, that will really constitute their *redemption* and their *state of grace.* It is to this point that morality, and the most perfect of all morality, that of Jesus, leads mankind. When at length this doctrine shall prevail throughout the world, the reign of the good and of the elect shall be established."

This language (as M. Barruel observes) is surely not enigmatical; and the profelyte who has heard it without shuddering, may flatter himself with being worthy of this Antichristian priesthood. He is led back to the porch, where he is invested with a white tunic and broad scarlet belt of silk. The sleeves of the tunic, which are wide, are tied in the middle and at the extremities with ribbons likewise of scarlet; and the candidate is recalled into the temple of mysteries. He is met by one of the brethren, who does not permit him to advance till he has declared "whether he perfectly understands the discourse which has been read to him; whether he has any doubts concerning the doctrines taught in it; whether his heart is penetrated with the sanctity of the principles of the order; whether he is sensible of the call, feels the strength of mind, the fervent will, and all the disinterestedness requisite to labour at the *grand undertaking*; whether he is ready to make a sacrifice of *his will*, and to suffer himself to be led by the most *excellent superiors of the order.*"

³² *Initiation to the priesthood.* The rites of the preceding degree were in impious derision of the sacrament of the Lord's supper; those of the present are an atrocious mimicry of sacerdotal ordination; at which, as every one knows, the Lord's supper is likewise celebrated. A curtain is drawn, and an altar appears with a crucifix upon it. On the altar is a bible; and the ritual of the order lies on a reading desk, with a censer and a phial full of oil beside it. The dean, or president, who acts the part of a bishop, blesses the candidate, cuts hair from the crown of his head, anoints him, clothes him in the vestments of the priesthood, and pronounces prayers after the fashion of the order. He presents him with a cap, saying, "Cover thyself with this cap; it is more precious than the royal diadem." The mock communion is then distributed; and it consists of milk and honey, which the dean gives to the profelyte, saying, "This is that which nature gives to man. Reflect how happy he would still have been, if the desire of superfluities had not, by depriving him of a taste for such simple food, multiplied his wants, and poisoned the balm of life." The ceremonies are terminated by delivering to the epopt that part of the code which relates to his new degree.

³³ *Duties of the priest or epopt.*

Among the instructions which it contains, the following are more particularly worthy of notice. The epopt, says the code, "will take care that the wri-

Illuminati. tings of the members of the order shall be cried up, and that the trumpet of fame shall be sounded in their honour. He will also find means of *binding the reviewers from casting any suspicions* on the writers of the sect." He is likewise instructed to *bribe* the common people into the interests of the order, and to corrupt their minds, by getting possession of schools and other seminaries of learning. But "if it be necessary for us to be masters of the ordinary schools (says the impious legislator), of how much more importance will it be to gain over the *Ecclesiastic Seminaries and their superiors!* With them we gain over the chief part of the country; we acquire *the support of the greatest enemies to innovation*; and the grand point of all is, that through *the clergy* we become *masters of the middle and lower classes of the people.*"

From the degree of epopt or priest are chosen the *regents or prince-illuminees.* On making this choice, says the code, three things of the utmost consequence are to be observed. "1st, The greatest reserve is necessary with respect to this degree: 2^{dly}, Those who are admitted into it, must be as much as possible *free men, and independent of princes*: 3^{dly}, They must have clearly manifested their *hatred of the general constitution*, or the *actual state of mankind*; and have shewn how evidently they wish for a *change in the government of the world.*" If these requisites be found in an epopt who aspires to the degree of regent, six preliminary questions are put to him; of which the obvious meaning is to discover, whether he deems it lawful and proper to teach subjects to throw off the authority of their sovereigns, or, in other words, to destroy every king, minister, law, magistrate, and public authority on earth.

³⁴ *Qualifications for the degree of regent.*

When these questions are answered to the satisfaction of his examiner, he is informed, "that as, in future, he is to be entrusted with papers belonging to the order of far greater importance than any which he has yet had in his possession, it is necessary that the order should have farther securities. He is therefore commanded to make his *will*, and insert a clause with respect to any private papers which he may leave, in case of sudden death. He is to get a formal or juridical receipt for that part of his will from his family, or from the public magistrate; and he is to take their promises in writing, that they are to fulfil his intentions." This precaution being taken, and the day fixed for his inauguration, he is admitted into an antechamber hung with black, where he sees a skeleton, elevated two steps, with a crown and sword lying at its feet. Having given up the written dispositions, &c. respecting his papers, his hands are loaded with chains as if he were a slave, and he is left to his meditations. A dialogue then takes place between his introducer and the provincial, who is seated on a throne in a saloon adjoining. It is in a voice loud enough to be heard by the candidate, and consists of various questions and answers; of which the following may serve for a specimen:

³⁵ *Admission to this degree.*

Prov. Who has reduced him to this state of slavery?

Ans. by the Introd. SOCIETY, GOVERNMENTS, the SCIENCES, and false RELIGION.

Prov. And he wishes to cast off this yoke, to become a seditious man and a rebel?

Ans. No; he wishes to unite with us, to JOIN IN

OUR

ILLUMINATI OUR FIGHTS AGAINST THE CONSTITUTION OF GOVERNMENTS, the corruption of morals, and the profanation of religion. He wishes, through our means, to become POWERFUL, that he may attain the GRAND ULTIMATUM.

Prov. Is he superior to prejudices? Does he prefer the general interest of the universe to that of more limited associations?

Ans. Such have been his promises.

Prov. Ask him, whether the skeleton which is before him be that of a king, a nobleman, or a beggar?

Ans. He cannot tell; all that he sees is, that this skeleton was a man like us; and the character of man is all that he attends to.

After a great deal of insidious mummery like this, the epopt is admitted to the degree of prince; but before his investiture with the insignia of that order, he is exhorted to be free, i. e. to be a man, and a man who knows how to govern himself; a man who knows his duty, and his imprescriptible rights; a man who serves the universe alone; whose actions are solely directed to the general benefit of the world and of human nature. "Every thing else (says the provincial) is INJUSTICE." A long panegyric is then made on the happiness which will be experienced by mankind, when every father of a family shall be sovereign in his tranquil cot! when he that wishes to invade these sacred rights shall not find an asylum on the face of the earth! when idleness shall no longer suffered; and when the *clod of useful sciences shall be cast aside* (c)!

The sign of this degree consisted in extending out the arms to a brother with the hands open; the gripe was to seize the brother by the two elbows, as it were to prevent him from falling; and the word was REDEMPTION! The epopt was invested with his principality by receiving a buckler, boots, a cloak, and a hat; and on receiving the boots, he was desired to fear no road which might lead to the propagation or discovery of happiness. Thus decorated, the prince illuminee received the fraternal embrace, and heard the instructions for his new degree.

One would think that the adept had now arrived at the very acmé of profaneness and treasonable conspiracy. He has been initiated in mysteries which burlesque Christianity and its Divine Author, and at the same time vow vengeance against all government, all law, and all science: yet Weishaupt, in a letter to Cato Zwack, his incomparable man, says, that he has composed four degrees above that of regent, or prince-illuminee; with respect even to the lowest of which, his degree of priest will be found no more than child's play. "The ritual of these degrees," (says he), I never suffer to go out of my hands. It is of too se-

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rious an import; it is the key of the ancient and modern, the religious and political, history of the universe."

This caution of the chief conspirator has deprived us of the power to give so particular an account of these degrees as we have done of the preceding; but the Abbé Barruel assures us that they were reduced to two, viz. that of MAGUS, and that of the MAN-KING; and that these two constituted the GREATER MYSTERIES. When the adept was admitted to the degree of magus, he was illumined only in philosophy and religion; when to that of man-king, new lights were given him respecting property, and every species of political association. The Abbé quotes a passage from the *Critical history of all the degrees of illuminism*, written by a man of honour, who had passed through them all, which will give the reader a sufficient idea of the object of these last degrees.

"With respect to the two degrees of magus and of man-king (says this writer), there is no reception, that is to say, there are no ceremonies of initiation. Even the elect are not permitted to transcribe these degrees; they only hear them read, and that is the reason why I do not publish them in this work. The first is that of Magus, called also philosopher. It contains the fundamental principles of Spinozism. Here every thing is material; God and the world are but one and the same thing: all religions are inconsistent, chimerical, and the invention of ambitious men."

That this is the doctrine of Spinoza, and that Spinoza was an atheist, is most certain; but though nothing can be essentially worse than atheism, we are strongly inclined to suspect that, at the initiation of the Magus, expressions must have been used more *so king* at least to the ear than the philosophic jargon of the apostate Jew. It is long since the philosophy of Spinoza was in Germany recommended from the press (see SPINOZA, *Encycl.*); it is but very lately that a professor in the university of Jena published a book, in which he teaches that there is no God, and that we absurdly give that title to the relations of Nature (D); and something approaching so near to atheism had been communicated to the adept when he was admitted to the priesthood, that we are persuaded Weishaupt must have alluded to language at least different from that in which Spinoza taught his dark doctrines, and that language, accompanied perhaps with impious and audacious gestures, when he said that, compared with his higher mysteries, his degree of priest was but child's play.

What gives some degree of probability to this conjecture, if it be nothing more, is the following fact related by the Abbé Barruel. During the French revolution (says that able and well-informed writer), a comedian appeared

5 F

(c) This will naturally surprize our readers; but it could not surprize him to whom it was addressed; for when candidate for the priesthood, he had been asked, "Do the sciences which men cultivate, furnish them with real lights? Are they conducive to real happiness? Are they not, on the contrary, the offspring of numberless wants, and of the unnatural state in which men live? Are they not the crude inventions of crazy brains?" There were, however, to be academies for the cultivation of such sciences as suited the designs of the order. Each academy was to consist of nine epopts, of whom seven were to preside respectively over so many departments of science, whilst the other two were to officiate as secretaries. One of the departments included the occult sciences, to which belonged the art of raising the seals of the letters of all who belonged not to the order, and of securing their own letters against similar practices!!

(D) We learned this from the letter already quoted in note (A).

Illuminati.
38
Atheism
and

appeared (E), dressed in the sacerdotal robes of the illuminees, and personally defying Almighty God. "No! (said the impious wretch) thou dost not exist. If thou hast power over the thunderbolts, grasp them; aim them at the man who dares set thee at defiance in the face of thy altars. But no! I blaspheme thee, and I still live. No! thou dost not exist." It will be seen by and bye, that the chiefs of the revolution, and even numbers of their tools, were illumined; and is it improbable that this blasphemer, who was arrayed in the insignia of the egypt, made use of the language and gestures of the higher mysteries? Whether it be or not, M. Barruel has proved, even from the writings of Weishaupt himself, that the magi were at least atheists of the school of Spinoza.

"The second degree of the grand mysteries, called the *Man-king*, teaches (according to the author of the *Critical History*), that every inhabitant of the country or town, every father of a family, is sovereign, as men formerly were in the times of the patriarchal life, to which mankind is once more to be carried back; that in consequence all authority and all magistracy must be destroyed."

39
Savagism.

This may appear to be nothing more than what the adept has been already taught in the lesser mysteries; and it is in fact nothing more than that to which he must have seen these mysteries tending; but the reader understands not the language of the illuminees, if he supposes that, by the patriarchal state, they mean such a state as that of the patriarchs of the Old Testament. No! their patriarchal state is the fancied savage state of the atheistical philosophers of Greece and Rome, when mankind had neither property nor fixed habitation. This is evident from one of the discourses of the hierophant; in which he tells the adept, that it would have been happy for man "had he known how to preserve himself in the primitive state in which Nature had placed him! But soon the unhappy germ developed itself in his heart, and rest and happiness disappeared. As families multiplied, the necessary means of subsistence began to fail. *The Nomade or roaming life ceased; property began; men chose fixed habitations; agriculture brought them together; LIBERTY WAS RUINED IN ITS FOUNDATIONS, AND EQUALITY DISAPPEARED.*"

To restore that liberty and equality, therefore, which is the ultimate object of the order, and constitutes the *MAN-KING*, all property must be abolished, every house burnt, as well the cottage of the peasant as the palace of the prince; and mankind must once more inhabit woods and caverns without clothes and without fire, and sally out occasionally to encounter their fellow-brutes, and to search for food among the wild herbs of the desert. According to Mochus the Phenician, and the Greek philosophers of this hopeful school, this was the original state of man*; and to this state it was the object of Weishaupt and his adepts to reduce man again. Hence we hear them lavishing the most rapturous encomiums on the Goths and Vandals who over-ran the Roman empire, annihilated the arts, put a stop to agriculture, and burnt the towns and villages of civilized Europe! It was thus, according to the illuminees,

* See
Doig's *Let-
ters on the
Savage
State.*

that those barbarians regenerated mankind: but the regeneration was not complete; for the Goths and Vandals could not preserve themselves from the contagion of civil life; and their fall from savagism to science drew from Weishaupt's hierophants the most piteous lamentations!

The last secret communicated to the most favoured adepts was the novelty of the order. Hitherto their zeal had been inflamed, and their respect demanded to an institution pretended to be of the highest antiquity. The honour of instituting the mysteries had been successively attributed to the children of the Patriarchs, to ancient philosophers, even to Christ himself, and to the founders of the masonic lodges (see *MASONRY* in this *Suppl.*). But now the time is come when the adept, initiated in the higher mysteries, is supposed to be sufficiently enthusiastic in his admiration of the order, to be entrusted with the history of its origin. Here then they inform him, that this secret society, which has so artfully led him from mystery to mystery; which has, with such persevering industry, rooted from his heart every principle of religion, all love of his country, and affection for his family; all pretensions to property, to the exclusive right to riches, or to the fruits of the earth;—this society, which has taken so much pains to demonstrate the tyranny and despotism of all laws human and divine, and of every government, whether monarchical, aristocratical, or republican; which has declared him free, and taught him that he has no sovereign on earth or in heaven; no rights to respect in others, but those of perfect equality, of savage liberty, and of the most absolute independence; that this society is not the offspring of an ignorant and superstitious antiquity, but of modern philosophy; in one word, that the true father of illumism is no other than Adam Weishaupt, known in the society by the name of *SPARTACUS!* This important secret, however, remained a mystery even to the greater part of the *magi* and the *man-kings*, being revealed only to the grand council of *areopagites*, and to a few other adepts of distinguished merit.

So zealously was the order bent upon propagating its execrable principles through the whole world, that some of the chiefs had planned an order of female adepts, in subserviency to the designs of the men. "It will be of great service, (says *Cato Zwack*), it will procure us both information and money, and will suit charmingly the taste of some of our truest members, who are lovers of the sex." An assessor of the Imperial chamber at Wetzlar, of the name of *Dittfurt*, but known among the illuminees by that of *Minos*, expressed even his despair of ever bringing men to the grand object of the order without the support of female adepts; and he makes an offer of his own wife and his four daughters-in-law to be first initiated. This order was to be subdivided into two classes, each forming a separate society, and having different secrets. The first was to be composed of virtuous women; the second of the wild, the giddy, and the voluptuous. The brethren were to conduct the first, by promoting the reading of good books; and to train the second-

Illuminati.
40
The last secret of the order.

41
Proposed for a female order.

(E) He does not say where this appearance was made; but the circumstances related lead us to suppose that it was in a church.

Illuminati, second to the arts of *secretly gratifying their passions*. The wife of an adept named Ptolemy Magus was to preside over one of the classes; which (says Minos) will become, under her management and his, a very pretty society. "You must contrive pretty degrees, and dresses, and ornaments, and elegant and decent rituals. No man must be admitted. This will make them more keen, and they will go much farther than if we were present, or than if they thought that we knew of their proceedings. Leave them to the scope of their own fancies, and they will soon invent mysteries which will put us to the blush, and mysteries which we can never equal. They will be our great apostles. Reflect on the respect, nay, the awe and terror, inspired by the female mystics of antiquity. Ptolemy's wife must direct them, and she will be instructed by Ptolemy; and my stepdaughters will consult with me. We must always be at hand to prevent the introduction of any improper question. We must prepare themes for their discussion: thus we shall confute them, and inspire them with our sentiments. No man, however, must come near them. This will fire their roving fancies, and we may expect rare mysteries!"

42
Rejected
by Sparta.
cus.

But notwithstanding all the plans and zeal of this profligate wretch and others of the fraternity, it does not appear that the General *Spartacus* ever consented to the establishment of the sisterhood. He supplied, however, the want of such an institution, by secret instructions to the regents, on the means of making the influence of women over men subservient to the order, without entrusting them with any of the secrets. "The fair sex (says he) having the greatest part of the world at their disposal, no study is more worthy the adept than the *art of flattery*, in order to gain them. They are all more or less led by vanity, curiosity, pleasure, or the love of novelty. It is on that side, therefore, they are to be attacked, and by that to be rendered subservient to the order." That Weishaupt's sagacity had not on this occasion forsaken him, is very evident; since it has been proved that the German fair, who were the correspondents of the illuminees, welcomed the French invaders of their native country*. Nay, so lately as the winter of 1798, our correspondent in Saxony heard several of these illumined ladies express a wish that the French might invade and conquer England; for then, said they, *tea and coffee would be cheaper!*

* Dr Robi-
son's Proof
of a Conspi-
racy.

It is not enough for the founder of a sect of conspirators to have fixed the precise object of his plots. His accomplices must form but one body, animated by one spirit; its members must be moved by the same laws, under the inspection and government of the same chiefs. A full account of the government of Weishaupt's order will be found in the valuable work of Abbé Baruel; our limits permit us to give only such a general view of it as may put our readers on their guard against the secret machinations of these execrable villains, whose lodges are now recruiting, under different denominations, in every country in Europe.

43
Subordina-
tion of the
illuminees.

Wherever illuminism has gained a footing, as the means of subordination, there is a general division of command as well as of locality. The *candidates* and *novices* are each under the direction of his own insinuator, who introduces him into the *Minerval lodges*; each *Minerval lodge* has a superior from among the preparatory class, under the inspection of the intermediary class. So

many lodges constitute a district, under the direction of **Illuminati**, a superior, whom the order calls *dean*. The dean is subjected to the *provincial*, who has the inspection and command of all the lodges and deaneries of the province. Next in order comes the *national superior*, who has full power over all within his nation, provincials, deans, lodges, &c. Then comes the supreme council of the order, or the *areopagites*, over which presides the *general* of illuminism. Thus has the order formed within itself a supreme tribunal, to whose inquisition all nations are to be subjected. The areopagites, consisting of twelve fathers of the order, with the general at their head, form the centre of communication with all the national superiors on earth; each *national* is the centre of one particular nation; the *provincial*, of one province; the *dean*, of the lodges within his deanery; the *Minerval master*, of his academy; the *venerable*, of his masonic lodge; and the *insinuator* or *recruiter*, of his *novices* and *candidates*.

The higher degrees (says Weishaupt in one of his instructions to the regents) must always be hidden from the lower. The simple illuminee therefore corresponds with his immediate superior, knowing perhaps no other member of the order; the latter, with his dean; and thus gradually ascending to the national superiors, who alone are acquainted with the residence of the areopagites, as they again are with the names and residence of the general. Any member, however, of the inferior degrees, may occasionally correspond with his unknown superiors, by addressing his letters *Quibus licet*; and in these letters he may mention whatever he thinks conducive to the advancement of the order. If he be a novice, he may in these letters inform his superiors how his instructor behaves to him, or may draw the character of any person whatever. When the letter of any adept contains secrets, or complaints which he chooses to conceal from his immediate superior, he directs it *Soli* or *Primo*; and then it can be opened only by the *provincial*, the *national superior*, the *areopagites*, or the *general*, according to the rank of the writer, which is by some contrivance unknown to M. Baruel, indicated on the outside of the letter. The *provincial* opens the letters of the *minor* and *major* illuminees which are directed *Soli*; the *Quibus licet* of the epopts; and the *Primos* of the novices; but he cannot open either the *Primo* of the minerval, the *Soli* of the Scotch knight, or the *Quibus licet* of the regent. He can only form a conjecture as to the persons who open his own letters, and those which he is not permitted to open himself.

When it is considered, that by one of Weishaupt's statutes, the provincial has in each chapter or district a confidential epopt, who is his *secret censor* or *spy*; that these spies are to insinuate themselves into all companies, and collect *anecdotes of secret history*; that the historian of the province is to insert these anecdotes into a journal kept for that purpose; and that the provincials are obliged to forward the contents of these journals to the high superiors of the order; some notion may be formed of the influence of the general and areopagites in every country into which illuminism has found its way. "The means of acquiring an ascendancy over men (says Weishaupt), are incalculable. Who could enumerate them all? They must vary with the disposition of the times. At one period, it is a

Illuminati taste for the marvellous that is to be wrought upon. At another, the lure of secret societies is to be held out. For this reason, it is very proper to make your inferiors believe, without telling them the real state of the case, that all other secret societies, particularly that of *Freemasonry*, are *secretly directed by us*. Or else, and IT IS REALLY THE FACT IN SOME STATES, THAT POTENT MONARCHS ARE GOVERNED BY OUR ORDER. When any thing remarkable or important comes to pass, hint that it *originated with our order*. Should any person by his merit acquire a great reputation, let it be generally understood that *he is one of us*.

46
By every
means,
good or
bad.

"If our order cannot establish itself in any particular place, with all the forms and regular progress of our degrees, *some other form must be assumed*. Always have *the object* in view; that is the essential point. No matter what *the cloak* be, provided you succeed; *a cloak*, however, *is always necessary*, for in *secrecy our strength lies*. THE MOST CONVENIENT CLOAKS FOR OUR GRAND OBJECT; because the world is already familiarised with the idea, that *nothing of importance, or worthy of their attention, can spring from masonry*." No artifice, however, is to be left untried. "You may attend large and commercial towns during the times of fairs in different characters; as *a merchant, an officer, an abbé*. Everywhere you will perforate an extraordinary man, having important business on your hands; but all this must be done with a great deal of *art and caution*, lest you should have the appearance of an adventurer. You may write your orders with a *chymical preparation of ink, which disappears after a certain time*. Never lose sight of the *military schools, of the academies, printing presses, libraries, cathedral chapters, or any public establishments* that can influence *education, or government*. Let our regents perpetually attend to the various means, and form plans, for *MAKING US MASTERS of all these establishments*. When an author sets forth principles true in themselves, but which do not as yet suit *our general plan of education for the world*, or principles, the publication of which is premature; every effort must be made to *gain over the author*; but should all our attempts fail, and we should prove unable to entice him into the order, *let him be discredited by every possible means*."

Of their methods of discrediting authors, one has come to our knowledge, which must be interesting to some of our readers. Dr Robison's work, entitled *Proofs of a Conspiracy, &c.* which first unmasked these hypocrites in this country, found its way into Germany, and was translated into the German language, and exposed to sale at the Leipzig fairs. The illuminees, under the disguise of *merchants and abbés*, attended, and bought up the whole impression, which they committed to the flames. A second edition was published, and it shared the same fate (F). This was a more compendious way of answering the learned author than that which has been adopted by the Jacobin journalists in London; but perhaps it may convince the readers of these journals, that the Doctor has not so far

mistaken the sense of the writings of *Philo* and *Spartacus*, as their illumined masters wish them to believe. Illuminati

When these arts of disseminating the disorganising and impious principles of the order are duly considered, and when it is remembered that its emissaries dare not disobey a single injunction of the high superiors, without exposing themselves to poison, or to the daggers of a thousand unseen assassins, no man can be surprised to learn that the illuminees contributed greatly to the French revolution. The philosophers of France had indeed prepared the public mind for embracing readily the doctrines of illuminism; and so early as 1782, *Philo* and *Spartacus* had formed the plan of illumining that nation; but they were afraid of the vivacity and caprice of the people, and extended not their attempts, at that time, beyond Strasbourg. Already, however, there existed some adepts in the very heart of the kingdom; and the Marquis de Mirabeau, when ambassador at the court of Berlin, was initiated at Brunswick by a disciple of *Philo Knigge's*. On his return to France he began to introduce the new mysteries among his masonic brethren.

47
Illuminism
of France

The state of free masonry was at that time peculiarly adapted to the views of the conspirators. The French had engrafted on the old and innocent British masonry a number of degrees, gradually rising above each other, to the very mysteries of illuminism itself (see MASONRY in this *Suppl.*) These were called the *philosophical degrees*, and comprehended the *knights of the sun*, the higher *Rosercrucians*, and the *knights Kadosh*. At the head of all these societies, whether ancient or modern, were three lodges at Paris, remarkable for the authority which they exercised over the rest of the order, and Philip of Orleans was the grand-master. So early as the year 1787, France contained 282 towns, in which were to be found regular lodges, under the direction of that execrable wretch. He increased their number by introducing to the *masonic* mysteries the lowest of the rabble, as well as those French guards whom he destined to the subsequent attack of the *baillie*, and to the storming of the palace of his near relation and royal master. In every country town and village lodges were opened for assembling the workmen and peasantry, in hopes of heating their imaginations with the sophisticated ideas of equality and liberty, and the rights of man; and it was then that Mirabeau invited a deputation from the order of Weisshaupt, which very quickly diffused the light of illuminism through the whole kingdom. Instead of *Spartacus Weisshaupt, Cato Zwack, and Philo Knigge*, we find wielding the firebrands of revolution in the capital of France, *Philip of Orleans, Mirabeau, Syeyes, and Condorcet*. The day of general insurrection was fixed by these miscreants for the 14th of July 1789. At the same hour, and in all parts of France, the cries of *equality* and *liberty* resounded from the lodges. The Jacobin clubs were formed; and hence sprung the revolution, with all its horrors of atheism, murder, and massacre!

48
By means
of free ma-
sonry.

In support of this account of the illuminees we have not loaded our margin with authorities; because our detail has been taken wholly from the valuable works

of

(A) This information was communicated to us by a gentleman of character, who was at Leipzig when the two impressions of the book were thus disposed of. The Abbé Barruel's work has no doubt been answered in the same way, though we cannot say so upon the same authority.

Illuminati. of Abbé Barruel and Dr Robison, to which we refer our readers for much curious information that our limits do not permit us to give. We cannot, however, conclude the article, without making some remarks on that specious principle by which the conspirators have deluded numbers, who abhor their impieties, and who would not go all their length even in rebellion; we mean the maxim, "that it is our duty to love all men with an equal degree of affection, and that any partial regard for our country, or our children, is unjust."

49
Reflections
on the fun-
damental
principles
of illumina-
nism;

That this maxim is false, every *Christian* knows, because he is enjoined to "do good indeed unto all men, but *more especially* to them who are of the household of faith;" because he is told, that "if any man provide not for his *own*, and especially for those of his *own house*, he hath denied the faith, and is worse than an infidel;" because his divine master, immediately after resolving all duty into the love of God and man, delivers a parable, to shew that we neither can nor ought to love all men *equally*; and because the same Divine Person had one disciple whom he loved more than the rest. But we with those *philosophers* who talk perpetually of the *mechanism* of the human mind, and at the same time affect to have no *partial* fondness for any individual, but to love all with the same degree of *rational* affection, to consider well whether such philanthropy be consistent with what they call (very improperly indeed) *mechanism*. If this mechanism be (as one of them says it is) nothing more than *attraction* and *repulsion*, we know that it cannot extend with equal force over the whole world; because the force of attraction and repulsion varies with the distance. If by this absurd phrase, they mean a set of *instinctive* propensities, or feelings, we know that among savages, who are more governed by instinct than civilized men, philanthropy is a feeling or propensity of a very limited range. If they believe all our passions to originate in self love, then is it certain that our philanthropy must be progressive; embracing first, and with strongest ardour, our relations, our friends, and our neighbours; then extending gradually through the society to which we belong; then grasping our country; and last of all the whole human race. Perhaps they may say that reason teaches us to love all men equally, because such equal love would contribute most to the sum of human happiness. This some of them indeed have actually said; but it is what no man of reflection can possibly believe. Would the sum of human happiness be increased, were a man to pay no greater attention to the education of his own children than to the education of the children of strangers? were he to do nothing more for his aged and helpless parents than for any other old person whatever? or, were he to neglect the poor in his neighbourhood, that he might relieve those at the distance of 1000 miles? These questions are too absurd to merit a serious answer.

When a man, therefore, boasts of his universal benevolence, declaring himself ready, without fee or reward, to sacrifice every thing dear to him for the benefit of strangers whom he never saw; and when he condemns, in the cant phrase of faction, that narrow policy which does not consider the whole human race as one great family—we may safely conclude him to be either a consummate hypocrite, who loves none but himself, or a philosophical fanatic, who is at once a

stranger to his duty and to the workings of his own heart.

If this conclusion require any farther proof, we have it in the conduct of Weishaupt and his areopagites. In the hand-writing of *Cato his incomparable man*, was found the description of a strong box, which, if forced open, would blow up and *destroy its contents*; several receipts for *procuring abortion*; a composition which *blinds or kills* when spurted in the face; *tea* for procuring abortion; *Herba que habent qualitatim delateream*; a method for filling a bed-chamber with *pestilential vapours*; how to take off impressions of seals, *so as to use them afterwards as seals*; a receipt *ad excitandum furorem uterinum*; and a dissertation on *suicide*. Would genuine philanthropists have occasion for such receipts as these? No! the order which used them was founded in the most consummate villainy, and by the most detestable hypocrite. The incestuous Weishaupt seduced the widow of his brother, and solicited poison and the dagger to murder the woman whom he had fondly pressed in his arms. "Execrable hypocrite (says M. Barruel), he implored, he conjured both art and friendship, to destroy the innocent victim, the child, whose birth must betray the morals of his father. The scandal from which he shrinks, is not that of his crime: it is the scandal which, publishing the depravity of his heart, would deprive him of that authority by which, under the cloak of virtue, he plunged youth into vice and error. *I am on the eve*, (says he) *of losing that reputation which gave me so great authority over our people: My sister in law is with child. I will hazard a desperate blow, for I neither can nor will lose my honour.*" Such is the benevolence of those who, banishing from their minds all partial affection for their children and their country, profess themselves to be members of one great family, the family of the world!

IMAGINARY QUANTITIES, or *Impossible Quantities*, in algebra, are the even roots of negative quantities; which expressions are Imaginary, or impossible, or opposed to real quantities; as $\sqrt{-aa}$, or $\sqrt[3]{-a^3}$, &c. For as every even power of any quantity whatever, whether positive or negative, is necessarily positive, or having the sign +, because + by +, or - by -, give equally +; hence it follows that every even power, as the square for instance, which is negative, or having the sign -, has no possible root; and therefore the even roots of such powers or quantities are said to be impossible or imaginary. The mixt expressions arising from imaginary quantities joined to real ones, are also imaginary; as $a - \sqrt{-aa}$, or $b + \sqrt{-aa}$.

IMAGINARY ROOTS of an equation, are those roots or values of the unknown quantity, which contain some imaginary quantity. Thus the roots of the equation $ax + aa = 0$, are the two imaginary quantities $+\sqrt{-aa}$ and $-\sqrt{-aa}$, or $+a\sqrt{-1}$ and $-a\sqrt{-1}$.

IMPACT, the simple or single action of one body upon another to put it in motion. Point of impact is the place or point where a body acts.

IMPERFECT NUMBER, is that whose aliquot parts, taken all together, do not make a sum that is equal to the number itself, but either exceed it, or fall short of it; being an abundant number in the former case, and a defective number in the latter. Thus, 12 is an abundant imperfect number, because the sum of all its aliquot parts, 1, 2, 3, 4, 6, makes 16, which exceeds the

Illuminati
||
Imperfect.
50
Exemplified in the conduct of the Illuminists.

^{Impul}
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^{Impulsion.}
the number 12. And 10 is a defective imperfect number, because its aliquot parts, 1, 2, 5, taken all together, make only 8, which is less than the number 10 itself.

IMPOST, in architecture, a capital or plinth, to a pillar, or pilaster, or pier, that supports an arch, &c.

^{Doctrine of}
^{Impul. sio.}
IMPULSION, is the term employed in the language of mechanical philosophy, for expressing a supposed peculiar exertion of the powers of body, by which a moving body changes the motion of another body by hitting or striking it. The plainest case of this action is when a body in motion hits another body at rest, and puts it in motion by the stroke. The body thus put in motion is said to be IMPELLED by the other: and this way of producing motion is called IMPULSION, to distinguish it from PRESSION, THRUSTING, or PROTRUSION, by which we push a body from its place without striking. The term has been gradually extended to every change of motion occasioned by the collision of bodies.

^r
^{History of}
^{it.}
When speculative men began to collect into general classes, the observations made during the continual exertions of our own personal powers on external bodies, in order to gain the purposes we had in view, it could not be long before they remarked, that as we, by the strength of our arm, can move a body, can stop or any how change its motion; so a body already in motion produces effects of the same kind in another body, by hitting it. Such observations were almost as early and as interesting as the other; and the attention was very forcibly turned to the general facts which obtained in this way of producing motion; that is, to the explication of the general laws of impulsion. We do not find, however, in what remains of the physical science of the ancients, that they had proceeded far in this classification. While mechanics, or the science of machines, had acquired some form, and had been the subject of successful mathematical discussion, we do not find that any thing similar had been done in the science of impulse. Yet the artillery of ancient times was very ingenious and powerful. But although Vegetius, and Ammianus Marcellinus, and Hero, describe the mechanism of these engines with great care; and frequently with mathematical skill, we see no attempts to ascertain with precision the force of the missile weapon, or to state the efficacy of the battering ram, by measures of the momentum, and comparison of it with the resistance opposed to it. The engineers were contented with very vague notions on these points.

Aristotle, in his 20th Mechanical Question, and Galen in some occasional observations, are the only authors of antiquity whom we recollect as treating the force of impulse as a quantity susceptible of measure. Their observations are extremely vague and trivial, chiefly directed, however, to the discrimination of the force of impulse from that of pressure.

In more modern times, great additions had already been made to the assistance we had derived from the impulsive efficacy of bodies in motion. Water-mills and wind-mills had been invented, and had been applied to such a variety of purposes, that the engineers were fast acquiring more distinct notions of the force of impulse. Naval constructions was changed in such a manner, that there hardly remained any thing of the ancient rigging. The oblique action of wind and water were

now found even more effective than the direct; and ships Impulsion- could now sail with almost any wind. All these things fixed the attention of the engineers and of the speculatist on the numberless modifications of the force of impulse.

But it soon appeared that this was a refined branch of knowledge, and required a more profound study than any other department of the science of motion. At the same time, it was equally clear, that it was also of superior importance. Mills worked by cattle, or by mens hands, were everywhere giving place to wind and water-mills; and a ship alone appeared to every intelligent mechanician to be the greatest effort of human invention, and most deserving his careful study. All these improvements in the arts of life derived their efficacy from the impulse of bodies. The laws of impulsion, therefore, became the objects of study to all who pretended to philosophical science. But this is a branch of study wholly new, and derives little assistance from the mechanical science already acquired; for that was confined to the determination of the circumstances which regulated the equilibrium of forces, either in their combined action on bodies in free space, or by the intervention of machines. But in the production of motion by impulse, the equilibrium is not supposed to obtain; and therefore its rules will not solve the most important question, "What will be the precise motion?"

Galileo, to whom we are indebted for the first discoveries in the doctrine of free motions, was also the first who attempted to bring impulsion within the pale of mathematical discussion. This he attempted, by endeavouring to state what is the force or energy of a body in motion. The very obscure reflections of Aristotle on this subject only served to make the study more intricate and abstruse. Galileo's reflections on are void of that luminous perspicuity which is seen in all his other writings, and do not appear to have satisfied his own mind. He has recourse to an experiment, in order to discover what pressure was excited by impulsion. A weight was made to fall on the scale of a balance, the other arm of which was loaded with a considerable weight; and the force of the blow was estimated by the weight which the blow could thus start from the ground. The results had a certain regularity, by which some analogy was observed between the weights thus started and the velocity of the impulse; but the anomalies were great, and the analogy was singular and puzzling; it led to many intricate discussions, and science advanced but slowly.

At last the three eminent mathematicians, Dr Wal-²
lis, Sir Christopher Wrenn, and Huyghens, about the Laws of
same time, and unknown to each other, discovered
the simple and beautiful laws of collision, and commu-
nicated them to the Royal Society of London in 1668
(Phil. Trans. n^o 43—46.) Sir Christopher Wrenn
also invented a beautiful method of demonstrating the
doctrine by experiment. The bodies which were made
to strike each other were suspended by threads of equal
length, so as to touch each other when at rest. When
removed from this their vertical situation, and then let
go, they struck when arrived at the lowest points of
their respective circles, and their velocities were propor-
tional to the chords of the arches through which they
had descended. Their velocities, after the stroke, were
measured,

Impulsion. measured, in like manner, by the chords of their arches of ascent. The experiments corresponded precisely with the theoretical doctrine.

In the mean time, this subject had keenly occupied the attention of philosophers, who found it to be of a very abstruse nature; or, which is nearer the truth, they indulged in great refinement in prosecuting the study. The first attempts to measure the impulsive force of bodies, by setting it in opposition to pressures, which had long been measured by weights, gave rise to some very refined reflections on the nature of these two kinds of forces. Aristotle had said that they were things altogether disparate. If so, there can be no proportion between them. Yet the analogy observed in the experiments above mentioned of Galileo, shewed that impulse could be gradually augmented, till it exceed any pressure. This indicates sameness in kind, according to Euclid himself. A curious experiment of Galileo's, in which the impulse of a vein of water was set in equilibrio with a weight, seemed not only to establish this identity beyond a doubt, but even to shew the origin of pressure itself. The weight in one scale is sustained as long as the stream of water continues to strike the other scale. In this experiment, therefore, pressure is equivalent to continual impulse. But *continual* impulse is not conceivable: we must consider the impulse of the stream as the *successive* impulse of the different particles of water, at intervals which are altogether indistinguishable.

From these considerations were deduced two very momentous doctrines: 1. That pressure is nothing but repeated impulse; 2. That although pressure and impulse are the same in kind, they are incomparable in magnitude. The impulse is equal to the weight of a column of water, whose length is the height necessary for communicating the velocity. Now this is incessant; and the weight is sustained during any the smallest moment of time, by the impulse, not of the whole column, but of the insensible portion of it which is then making its stroke. Impulse, therefore, is infinitely greater than pressure.

These abstruse speculations have a charm for certain ingenious speculative minds; and when indulged, will lead them very far. Accordingly, it was not long before some of the most ingenious philosophers of Europe taught that impulse was the sole origin of pressure. There is but one moving power (said they) in mechanical nature: This is impulse.—*Nihil movetur* (says Euler) *nisi a contiguo et moto*. Moreover, having been long and familiarly conversant with the actions of animals, and the actions of moving bodies, and conceiving, with sufficient distinctness, that impenetrable bodies cannot move without moving those with which they are surrounded and in contact, they imagined that they fully understood how all this displacement of bodies is carried on; and therefore they maintained, that any motion is fully explained when it is shewn to be a case of impulsion. But they saw many cases of motion where this impulsion could not be exhibited to the senses. Thus, the fall of heavy bodies, the mutual approach or recess of magnetic and electric bodies, exhibited no such operation. But even here their experience helped them to an explanation. Air is an invisible substance, and its very existence was for a long time known to us only by means of its impulse. As we see that pressures

are generated by the impulse of water and of air, may there not be fluids still more subtle than air, by whose invisible impulse bodies are made to fall, and magnets are made to approach or avoid each other? The impossibility of this cannot be demonstrated, and the laws of impulse had not as yet been so far investigated as to shew that they were incompatible with those productions of motion. It was therefore an open field for discussion; and the philosophers, without farther hesitation, adopted, as a first truth, that **ALL MOTION WHATSOEVER IS PRODUCED BY IMPULSION**. The business of the philosopher, therefore (say they), is to investigate what combination of invisible impulsions is competent to the production of any observed motion; such as the fall of a heavy body, the elliptical motion of a planet, or the polarity of a magnetic needle. The curious disposition of iron-filings round a magnet encouraged this kind of speculation: It looks so like a stream of fluid; but it is a number of quiescent fragments of iron. This does not hinder us from *supposing* such a stream, not of iron-filings, but of a magnetic fluid, which will arrange (say the atomists) those fragments, just as we see the stote-grafs in a brook arranged by a stream of water. Fluids, therefore, moving in streams, vortices, and a thousand different ways, have been supposed, in order to *explain*, that is, to bring under a general known law of mechanical Nature, all those cases of the production of motion where impulsion is not observed by the senses.

As we have gradually become better acquainted with the laws of the production of motion by impulsion, we have been able to explode many of those proffered explanations, by shewing that the genuine results of the supposed invisible motions, that is, the impulsions which they would produce, are very unlike the motions which we attempt to explain. It has been shewn that the vortices supposed by Des Cartes, or by Leibnitz, or by Huyghens, cannot exist; and they have been given up. But it is answered to all those demonstrations of futility, that still the axiom remains. Motion is produced only by impulse; but we have not yet discovered all the possibilities of impulsion; and we must not despair of discovering that precise set of invisible motions, and consequent impulsions, of which the phenomena before us is the necessary result.

But this is by no means sufficient authority for deserting the rule of philosophizing, so prudently and judiciously recommended by Sir Isaac Newton; namely, not to admit as the cause of phenomenon any thing that is not *seen* to operate in its production. The prudence of this restriction is evident; and it has also been sufficiently shewn (PHILOSOPHY, *Encycl.* n^o 48. &c.), that true philosophical explanation, or extension of knowledge, is unattainable, if this rule be not strictly adhered to. We therefore require a cogent reason for a practice that opens the door to every absurdity, and that cannot give us the knowledge which we are in quest of. What, then, is the reason that always induces philosophers to have recourse to impulsion for the explanation of a phenomenon, and to rest satisfied in every case where it can be clearly proved that the phenomenon is really a case of impulsion? We say that we inquire into the reason why a body falls, and that we will be satisfied if it can be shewn us that it has received a number of impulsions downward. Do we inquire why

3
Impulse
said to be
the only
cause of
motion.

Impulsion. a body in motion puts another body in motion by hitting it? And if we do, have we discovered the reason? We believe that none of the philosophers, who have recourse to invisible impelling fluids, ever ask a reason for motion by impulsion. Indeed they should not, otherwise it would cease to be a first principle of explanation. Other philosophers, indeed (namely, such as ask no reason for the weight of a body, but the FIAT of the ALMIGHTY), require an explanation of motion by impulse, and think that, in almost every case, they have found it out.

If the philosophers ask no reason for this production of motion, they must (that it may serve as a principle of explanation) say that impulsiveness is an original property of matter, either contingent or essential. Accordingly, we believe that this, or something like this, has been assumed as a principle by the greater part of mechanicians. It has been assumed, as we have observed in the article DYNAMICS, *Suppl.* that a *moving body* possesses the power of producing motion in another body by hitting it; and they call it the IMPULSIVE FORCE of moving bodies—the FORCE INHERENT in a moving body. The reader will have observed, in our manner of treating that article, and also in several passages of different articles of the *Encyclopædia Britannica*, that we do not consider this assumption as very clearly authorized by observation, or deducible by abstract reasoning, from the first principles of philosophy. There is no branch of natural philosophy on which so many ingenious dissertations have been written; and perhaps there is none that has been more successfully prosecuted: Yet this is the only part of the science of motion that has given rise to a serious dispute; a dispute that has divided, and still divides, the mechanicians of Europe.

Some may think it presumptuous in us, in a Work of this kind, which only aims at collecting and exhibiting in one view the *existing science* of Europe, to pretend to give new doctrines, or to decide a question which has called forth all the powers of a Leibnitz, a Bernoulli, a Jurin, a M^r Laurin, &c. But we make no such pretensions; we only hope that, by separating the question from others with which it has, in every instance, been complicated, and by considering it apart, such notions may be formed, in perfect conformity to the principles adopted by all parties, that the mystery, which has gradually gathered like a cloud, may be dispelled, and all cause of difference taken away. We apprehend that this requires no very extensive knowledge, but merely a strict attention to the conceptions which we form of the actions of bodies on each other, and a precision in the use of the terms employed in the discussion.

⁵
Inquiry into its truth.

We trust that our philosophical readers perceive and approve of our anxiety to establish (in the article DYNAMICS, *Suppl.*) the leading principles of mechanical philosophy, from which we are to reason in future on acknowledged FACTS, or LAWS of human thought. It is not so much the question, What is the essence of material Nature, from which all the appearances in the universe proceed? as it is, What do we know of it? how do we come by this knowledge? and what use can we make of it? The tænia knows nothing of the solar system, and man is ignorant of the cause of impulsiveness. Other intelligent creatures may have senses, of which this is the proper object; and others, of a still

more exalted rank, may perceive the operations of mind as clearly as we perceive those of matter, while they are equally ignorant with ourselves of the causes which connect the conjoined events in either of those operations. But “known unto GOD, and to HIM alone, are ALL His works!”

Impulsion.

To accomplish this purpose, we directed the reader's attention to what passes in his own mind when he thinks the mechanical phenomena of Nature; on what he calls body; on the perceptions which bring it into his view, and which give him all the notions that he can form of its distinguishing, its characteristic properties. How does he learn that there is matter in a particular place? He has more than one mean of information; and each of these informs him of peculiar qualities of the thing which he calls *matter*. Many appearances suggest to his mind the presence of a body. Shew a monkey or a kitten (and even sometimes a human infant) a mirror, and it will instantly grope round it to find a companion. Why does the creature grope about so? It is not contented with the first indication of matter, and nothing will satisfy it but touching or grasping what is behind the mirror. It is by our sense of touch alone that we get the irresistible conviction that matter or body is perceived by us, and it never fails to give us the perception; nay, we have the perception even in some cases where the experienced philosopher thinks himself obliged to doubt of its truth. Some sensations, arising from spasm, cannot be distinguished from the feeling of touch; and the patient insists that something presses on the diseased part, while the physician knows that it is only a nervous affection. Every person will think that a cobweb touches his face when an electrified body is brought near it, and will try to wipe it off with his hand. But the modern philosopher sees good reason for asserting, that in this instance our feeling gives us very inaccurate, if not erroneous, information. He shews that the fact, of which our feeling truly informs us, is the bending of the small hairs or down which grow on the face, and that these only have been touched; and the followers of Epinus deny that even this has been demonstrated.

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The excite-
ment of
touch is ac-
companied
by the feel-
ing of ex-
tended pres-
sure.

The philosopher adopts this mode of perception as unquestionable, and allows that, and that alone, to be matter, which invariably produces this sensation by contact. But engaged in speculations which fix his attention on the external object, he neglects and overlooks the instrument of information, and its manner of producing the effect, just as the astronomer overlooks the telescope, and the union and decussation of the rays of light which form the picture by which he perceives the satellite of Jupiter travel across his disk. The philosopher finds it convenient to generalise the immense variety of touches which he feels from external bodies, and to consider them as the operations of one and the same discriminating quality, a PROPERTY inherent in the external substance BODY: and he gives it a name, by which he can excite the same notion in the minds of his hearers. It is worth while to attend to what has been done in this matter, because it gives much information concerning the first principles of mechanism. An exquisite painter has sometimes such an appearance of prominence, that one is disposed to draw the finger along it, and we expect to feel some roughness, some *obstruction*, something that prevents the finger

ger

Impulsion, ger from going over the place. Perhaps we doubt, and want to be assured. We press a little closer; but feel no obstruction; and we desist. The very first appearance, therefore, which this indicating quality, viewed as the *property* of external matter, has in our conceptions, is that of an obstruction, an obstacle, to the exertion of one of our natural powers. The power exerted on this occasion is familiarly and *distinctively* known by the name of PRESSURE. This is the name of our own exertion, our own action; and, in this instance, and (we think, in this alone, the word is used purely, primitively, and without figure. When we say that a stone presses on the ground, we speak figuratively, as truly as when we say that the candlestick stands, and the snuffers lie, on the table. It is a personification, authorized by the similarity of the effects and appearances. Further, when we speak of our pressure on any thing, with the intention of being precise in our communication, we speak only of what obtains in the touching parts of the finger and the thing pressed, paying no attention to the long train of intermediate exertions of the mind on the nerves, the nerves on the muscular fibre, the fibre on the articulated machine, and the machine on the touching part of the finger. And thus the exertion of the sentient and active being is attributed to the particles of lifeless inactive matter at the extremity of the finger, and these are said to press immediately on the touching parts of the external body. And, lastly, as this our exertion is unquestionably the perceived employment of a faculty in us, which we call *force, power, strength*, distinguishing it from every other faculty by these names; we say (but figuratively), that force or power is exerted at the tips of the fingers, and we call it the FORCE OF PRESSURE.

8
And pressure is conceived or supposed in almost every production of motion.

By far the greatest part of our actions on external bodies is with the intention of putting them out of their present situations; and we can hardly separate the thought of exerted pressure from the thought of motion produced by it. Therefore, almost at its first appearance in the mind, pressure comes before us as a MOVING POWER. Nay, we apprehend, that the more we speculate, and the more we aim at precision in our conceptions, we shall be the more ready to grant that we have no clear *conception* of any other moving power. No man will contend that he has any conception at all of the power exerted by the mind in moving the body. It is of importance to reflect on the manner in which this notion is extended to all other productions of motion. We think that this will shew, that in every case we suppose pressure to be exerted.

9
Examination of the instances of this perception.

The philosopher proceeds in his speculations, and observes that one man can press on another, and can push him out of his place, in the same way as he removes any other body; and he cannot observe any difference in his own exertions and sensations in the two cases. But the man who is pushed has the same feelings of touch and pressure. By withdrawing from the pressure, he also withdraws from the sensation; by withstanding or resisting it, he feels the pressure of the other man; and what he feels is the same with what he feels when he presses on the other person, or on any piece of matter. The same sensations of touch are excited. He attributes them to the pressure of the other person. Therefore he attributes the same sensations to the counter pressure of any other body that excites them. Far-

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ther, he can resist to such a degree that he is not pushed from his place. In this case, the greatest pressure is exerted, and is felt by both. Each feels that the more he resists, the greater is the mutual pressure. And each feels that, unless he *not only do not resist, but also withdraw himself* from the pressure of the other, he will be pressed, and the other will feel counter pressure, the same in kind with what is produced by his resistance, though less in degree.

All these things are distinctly and invariably felt; They are but they require attention, in order to be subjects of generally recollection and after-consideration. From this, and no other sources, are derived all our notions of corporeal pressure, of counter pressure, of action, reaction, of *resistance*, and of *inactivity* or *inertia*. Our notions of moving power, of the mobility of matter, and of the necessity of this power to produce motion in matter, have the same origin. Our notions also of the resistance of inanimate matter, indicated by the expenditure of actual pressure, are formed from the same premises: the counter-pressure, or what at least produces the same feelings in the person who is the mover, is considered as the property of dead matter; because we feel, that if *we* do not exert real force, we are displaced by the same pressure that would displace a lifeless body of the same bulk.

These direct inferences are confirmed as we extend our acquaintance with things around us. We can exert our force in bending a spring, and we feel its counter-pressure, precisely similar to that of another man. We feel that we must continue this pressure, in order to keep it bent; and that as we withdraw our pressure, the spring follows our hand, still producing similar feelings in our organs of touch, and requiring similar exertions of our strength to keep it in any state of tension. These phenomena are interpreted as indications of pressures actually exerted by the spring, and quite different from what we should feel from its mere resistance to being moved. This action resembles our own exertion in every particular; it produces all the effects of pressure; it will squeeze in the soft flexible parts of our body with which we act on it; it will compress any soft body, just as we do ourselves; it will put bodies in motion. Farther, we can set the action of one spring in opposition to that of another, and observe that each is bent by bending the other; and we see that their touching parts exert pressure, for they will compress any soft body placed between them.

Thus, then, in all those cases, we have the same notion of the power immediately exerted between the two bodies, animated or inanimated. It is always pressure. If indeed we begin to speculate about the *modus operandi* in any one of these instances, we find that we must stop short. How our pressure excites the feeling of pressure in the other person, or how it produces motion, eludes even conjecture—So it is—Nay, how our intention and volition causes our limb to exert this pressure, or how the springiness of a spring produces similar effects, remains equally hid from our ken. Unwearied study has greatly advanced our knowledge of these subjects in one respect. It has pointed out to us a train of operations, which go on in our animal frame before the ostensible pressure is produced; we have discovered something of their kind, and of the order in which they proceed; we have gone farther, and have discovered, in

Impulsion. some of the pressures exerted by lifeless matter, similar trains of intervening operations. In the case of a spring, we have discovered that there is a certain combination of the properties of all its parts necessary for the visible exertion. But what is the principle which thus makes them co-operate, we cannot tell, any more than in our own exertions of pressure. Such being the origin of our notions on these subjects, it is no wonder that all our language is also derived from it. Force, power, pressure, action, re-action, resistance, impulsion, are, without any exception, words immediately expressive of our own exertions, and applied metaphorically to the phenomena of matter and motion.

Lastly, when we see a body in motion displace another body by hitting it, and endeavour to form a notion of the way in which this motion is immediately produced, fixing our attention on what passes in the very instant of the change, we find ourselves still obliged to suppose the thing we call pressure. We can have no other conception of it; and there is no violence in this act of the imagination. For we know, that if we are jostled from our place, and forcibly driven against another person, we put that person in motion without any intention or action of our own; and we experience, in doing this, that the very same feelings of touch and pressure are excited as in the instances of the same motions produced by exerted pressure. We also see, that when a body strikes another, and puts it in motion, it makes an impression or dimple in it if soft, or breaks it if brittle; and, in short, produces every effect of pressure. A ball of soft clay makes a dimple in the ball of soft clay which it displaces, and is dimpled by it. Springy bodies compress each other in their collisions, and resist from each other. In short, in every case of this class, mutual pressure, indicated by all its ordinary effects, appears to be the intermedium by which the changes of motion are immediately produced; and the previous motion of the striking body seems to be only the method of producing this pressure.

¹² Pressure is the only distinct notion of a moving power.

From this curious induction of particulars, and careful attention to the circumstances of each, we think it plain, that pressure is the only clear notion that a mind, not familiar with scrupulous discussion, forms of moving power; and therefore that it is very singular to think of excluding it from the list, and saying that impulsion is the only power in nature, and the source of all pressure.

It may perhaps be said, that the mutual immediate action to which the vulgar, and many philosophers, have erroneously given the metaphorical name pressure, is indeed the real cause of motion, or change of motion; but still it is now properly called impulsion, because it is occasioned only by the previous motion of the impelling body. We conceive clearly (they may say) how this previous motion produces the impulsion. Since matter is impenetrable, we see clearly that a solid body, or a solid particle, cannot proceed without displacing the bodies with which it comes into contact; we have notions of this as clear as those of geometry; whereas, how pressure is produced, is inconceivable by us. If we press a ball ever so strongly against another, and remove the obstacle which prevented its motion, it will not move an inch, unless we continue to follow it, and press it forward; but we see a moving body produce compression, bend springs, make pits in soft bo-

odies, and produce all the effects of real animal pressure. **Impulsion.** Impulse, therefore, is the true cause of motion, and the solicitation of gravity is nothing but the repeated impulse of an invisible fluid.

But, in the first place, let it be observed, that both parties profess to explain the phenomena of mechanical nature, that is, to make them easier conceived by the mind. Now it may be granted, that could we have any previous conviction of a fluid continually flowing toward the centre of the earth, we could have some notion of the production of a downward motion of bodies, but not more explanation than we have without it, because impulsiveness is as little understood by us as pressure.

But there are thousands of instances of moving forces where we cannot conceive how they can be produced by the impulse of a body already in motion. There appear to be many moving powers in nature, independent of, and inexplicable by, any previous motion; these may be brought into action, or occasions may be afforded for their action, in a variety of ways. The mere will of an animal brings some of them into action in the internal procedure of muscular motion; mere vicinity brings into action powers which are almost irresistible; and which produce most violent motions. Thus a little aquafortis poured on powdered chalk contained in a bombshell, will burst it, throwing the fragments to a great distance. A spark of fire brings them into action in a mass of gunpowder, or other combustibles. And here it deserves remark, that the greater the mass is to which the spark is applied, the more violent is the motion produced. It would be just the contrary, if the motion were produced by impulse. For in all cases of impulsion, the velocity is inversely proportional to the matter that is moved. When a spring is bent, and the two ends are kept together by a thread, a pressure is excited, which continues to act as long as the thread remains entire. What contrivance of impelling fluid will explain this, or give us any conception of the total cessation of this pressure, when the thread is broken, and the spring regains its quiescent form?

¹³ Many pressures are inexplicable by impulsion.

We can explain, in a most intelligible manner, why the hardest pressure produces no sensible motion in the case referred to above. We can conceive, with sufficient distinctness, a tube filled with steel wires, coiled up like cork screws, and compressed together into $\frac{1}{16}$ th of their natural length. A tube of 10 inches long will contain 100 of them. While in this state, compressed by a plug, we can suppose each of the springs to be tied with a thread. Suppose now that the thread of the spring next the piston is burnt or cut; it will press on the piston, and force it out, accelerating its motion till it has advanced one inch; after this, the piston will proceed with a uniform motion. It is plain that the velocity will be moderate, perhaps hardly sensible, because the pressure acted on it during a very short time. But if two springs have been set at liberty at the same instant, the pressure on the piston will be continued through a space of two inches, and the final velocity will be greater, because the same (not a double) pressure will be exerted through a double space. Unbending four springs at once, will give the piston a double velocity (See DYNAMICS, *Suppl.* n^o 95.). Now the effect of the motion of the second spring is to keep the pressure of the first

¹⁴ All pressures do not produce a sensible motion.

Impulsion. first in action during a longer time, by following it, and keeping it in a state of compression. There is nothing supposed of this kind in the case of strong pressure alluded to; and therefore no motion is produced when the obstacle is removed, except what the insensible compression produces by accelerating the body along an insensible space. If all the 100 springs are disengaged at once, the piston will be accelerated through 100 inches, and will acquire ten times the velocity that one spring can communicate. (*N. B.* The force expended in moving the springs themselves is not considered here).

It is in this way only that the previous motion of the impelling body acts in producing a considerable motion. The whole process will be minutely considered by and bye.

15
Impulsion is not more clearly conceived than pressure.

We may now ask, how it is so clear a point, that a solid body in motion must displace other bodies? This seems to be the very point in question. Is the affirmative deduced from our notion of solidity? What is our notion of solidity, and whence is it derived? We apprehend that even this primary notion is derived from pressure. It is by handling a thing, and finding that we cannot put our hand into the place where it is without displacing it, that we know that it is material. All this is indicated to us by the feeling excited by our pressure. We feel this property always as an obstacle; and therefore say, that by this property it resists our pressure. Nay, there are cases where even the philosopher prefers this quality to impulsiveness as a test of matter. To convince another that the jar out of which he has poured the water that filled it is not empty, but full of matter, he dips the mouth of the jar into water, and shows, that although he presses it down till the surrounding water is above the bottom of it, the water has hardly gotten half an inch into the jar; there is something there which keeps it out; there is matter in it. He then opens a hole in the bottom of the jar; the water immediately rises on the inside of the jar, and fills it. He says that the pressure of the water has driven the matter out by the hole; and he *confirms* the materiality of what is expelled by holding a feather above the hole. It is agitated, shewing that the expelled thing has impulsiveness, another property (he says) of matter: what filled the jar was air, and air in motion is wind. The philosopher can exhibit some new cases, where something like impulsiveness appears. A slender magnet may be set on one end, the south pole, for instance, and will stand in that tottering situation. If a person bring the north pole of a powerful magnet hastily near the upper end, it will be thrown down, just as it may be blown down by a puff of wind; therefore (says the philosopher) there may be appearances of impulsion, and I may imagine that there is impelling matter; but nothing but matter excludes all other matter from its place: this property, therefore, is the surest test of its presence.

Thus we see, that our notion of solidity or impenetrability (a name still indicating an obstacle to pressure), gives us no clearer conception of the productions of motion by impulsion than pressure does; for it is the same, or indicated by the same sensations.

16
Motion does not impel by transferring inherent force or inherent motion.

The question now seems to be reduced to this—Since the strongest pressure of a quiescent body does not produce motion, or excite that kind of pressure which is the immediate cause of motion, while a body in mo-

Impulsion. tion, exciting but a very moderate pressure (as may be seen by the trifling *compression* or dimpling), produces a very considerable motion, how is the previous motion conducive to this purpose? The answer usually given is this: A body in motion (by whatever cause) perseveres in that motion by the *inherent force*; when it arrives at another body, it cannot proceed without displacing that body. The nature of the inherent force is such, that none of it is lost, and that a portion of it passes into the other body, and the two bodies instantly proceed with the same quantity of motion that was in the impelling body alone. This is an exact enough narrative of the general fact, but it gives no great *explanation* of it. If the impelling body perseveres in its motion by means of its inherent force, that force is exerted in performing its office, and can do no more. The impelled body seems as much to possess an inherent force; for the same marks and evidences of pressure on both sides are observed in the collision. If both bodies are soft or compressible, both are dimpled or compressed. We are as much entitled, therefore, to say, that part of the force by which it perseveres at rest, passes into the other body. But the rest, or quiescence of a body, is always the same; yet what passes into the impelling body is different, according to its previous velocity. We can form no conception how the half of the inherent force of the impelling body is expended by every particle, passes through the points of contact, and is distributed among the particles of the impelled body; nay, we cannot conceive this halving, or any other partition of the force. Is it a thing *sui generis*, made up of its parts, which can be detached from each other, as the particles of salt may be, and really are, when a quantity of fresh water is put into contact with a quantity of brine? We have no clear conception of this; and therefore this is no elucidation of the matter, although it may be an exact statement of the visible fact.

17
This involves absurdities.

Let us take the simplest possible case, and suppose only two particles of matter, one of which is at rest, and the other moves up to it at the rate of two feet per second. The event is supposed to be as follows: in the instant of contact, the two particles proceed with half of the former velocity. Now this instant of time, and this precise point of space, in which the contact is made, is not a part of either the time or space before collision, or of those after collision; it is the boundary between both; it is the last instant of the former time, and the first instant of the latter time; it belongs to both, and may be said to be in both. What is the state or condition of the impelling particle in this instant? In virtue of the previous motion, it has the determination, or the force, or the power, to move at the rate of two feet per second; but, in virtue of the motion after collision, it has the determination or power of moving at the rate of one foot per second. In one and the same instant, therefore, it has two determinations, or only one of them, or neither of them. And it may, in like manner, be said of the impelled body, that, in that instant, it was both at rest, and moving at the rate of one foot per second. This seems inconceivable or absurd.

18
Impulsive-ness is not an intuitive property of matter.

It is not perhaps very clear and demonstrable, nor is it intuitively certain, that the moving body or particle must displace the other at all. All that we know is, that matter is moveable, and that causes of this

Impulsion. motion exist in nature. When they have produced this motion, they have performed their task, and the motion is their complete effect: the particle continues in this condition for ever, unless it be changed by some cause; but we do not see any thing in this condition that enables us to say what causes are competent to this change, and what are not. Is it either intuitive or demonstrable, that the mere existence of another particle is not a sufficient or adequate cause? Is it certain that the arrival at another particle is an adequate cause? or can we prove that this will not stop it altogether? The only conclusion that we can draw with any confidence is, that "two particles, or two equal bodies, meeting with equal velocities, in opposite directions, will stop." But our only reason for this conclusion is, that we cannot assign an adequate reason why either should prevail. But this form of argument never carries luminous conviction, nor does it even give a decision at all, unless a number of cases can be specified which include every possible result. This can hardly be affirmed in the present case.

19
But an observed fact.

We apprehend that the next case, in point of simplicity, has still less intuitive or deductive evidence; namely, when bodies meet in opposite directions with equal quantities of motion. It is by no means easy, if it be at all possible, to shew that they must stop. The proof proceeds on some notion of the manner in which the impulsion, exerted on one particle, or on a few of each body, namely, those which come into contact, is distributed among all the particles. A material atom is moved only when a moving force acts on it, and each atom gets a motion precisely commensurate to the force which actuates it. Now, it is so far from being clear, how a force impressed on one particle of a solid body occasions an equal portion of itself to pass into every particle of that body, and impel it forward in the same direction, that the very authors who assume the present proposition as an elementary truth, claim no small honour for having determined with precision the moving forces that are exerted on each particle, and the circumstances that are necessary for producing an equal progressive motion in each. It was by no means an easy problem to shew, that the motion of the body (estimated by an average taken of the motions of every particle) is precisely that which is announced by this proposition. We must also consider how this investigation is conducted. It is by assuming, that whatever force connects a particle *a* with a particle *b*, or whatever force *a* exerts on *b*, the particle *b* exerts an equal force on *a* in the opposite direction—Surely no logician will say that this is an intuitive truth. The contrary is most distinctly conceivable. It was a discovery of the astronomers, that every deflection toward the sun is accompanied by an equal deflection of the sun. It was a discovery, that a piece of iron attracts a loadstone; and it was a discovery (and we dare not yet affirm it to be without exception), that every action of bodies is accompanied by an equal and contrary reaction. But this is by no means a first principle. It is the expression of a most generally observed fact, a sum total of knowledge. When received on this authority, it is fully competent to solve every case of impulsion, independent of all obscure and illogical doctrines of force inherent in moving bodies, of force of inertia, of communication of motion, &c.

The impossibility of conceiving the detachment of **Impulsion.** part of the force inherent in *A*, and transferring this part into *B*, and the similar impossibility of conceiving the imparting to *B* some of the motion that was in *A*, should make us reject any proposition involving such conceptions, and refuse its admission as an elementary truth. Much more should we reject a proposition that obliges us to suppose that a particle of matter has two determinations, forces, motions, or call them by any other name, in one and the same instant. One of these necessarily excludes the other. Indeed this was so evident, even to the most eminent partizans of the doctrine of the transfusion of inherent force, and others consequent on it, that they found themselves obliged to deny that there was such a thing in the world as a perfectly hard body, in which the motion must be instantaneously changed into another, differing from it by any sensible quantity. The existence of perfectly hard bodies is positively denied by the celebrated mathematician of Basle, John Bernoulli, in his Dissertation on the Communication of Motion, which contended for the prize given by the Academy of Sciences at Paris 1710. His reason for this rejection is singular, and somewhat amusing. "In the collision of perfectly hard bodies, the *conservatio virium vivarum*, demonstrated by the most eminent mathematician (Mr Leibnitz), to be a law of nature, would be broken without any effect being produced. He does not observe, that it is as completely broken by elastic bodies in the instant of greatest compression. A British philosopher, *nullius in verba* jurare in verba magistri, asked, What will be the case of two encountering atoms of matter? Without calling them hard, we must conceive that they acquire their changes of motion in the instant of mutual contact, and that they acquire them totally, being *ατομικῶς*, indivisible. No answer has been given, or indeed can be given, but what implies the same difficulty. From all that has been said, we must conclude, that this branch of mechanical philosophy is not put, by those philosophers, into the condition of an elementary foundation of clear and demonstrative science; that the transfusion, or transference, either of force or motion, is not a thing of which we have a distinct conception; and that it necessarily leads us into very untenable doctrines. Far less does it seem safe for us to confide so much in its clearness and certainty, as to affirm, that impulsion is the sole moving force in mechanical nature, and the source of what we call pressure.

All this difficulty and obscurity has arisen from our arrogant notion, that we are competent judges of first principles; whereas we must acknowledge, that we can only perceive such as are properly related or accommodated to our intellectual powers: these powers, being specific and peculiar, cannot judge of principles of the first class, but of those only that are suitably compounded. We can never know or comprehend any essential property of matter—we can only know the relative properties of such matter as we see.

Therefore let us quit entirely the barren and trackless fields of abstraction, and rest satisfied with contemplating ^{to be learned only by observing nature.} what the Author of Nature has exhibited to our view, and such as he has been pleased in his wisdom to exhibit it. We grant that there are no bodies open to our inspection which are perfectly hard, receiving finite changes of motion in an instant. It has not pleased

Impulsion. God to put any such within our reach. When God created matter, it was with the purpose of forming a beautiful universe of this matter. He therefore gave it properties which fitted it for this purpose. It is this matter only that he has exposed to the wondering view of man. Thanks to his bounty, he has also given us properties of mind, by which this adaptation, when perceived by us, becomes a source of dignified pleasure to the observer.—A Newton, to whom "*Jovis omnia plena*," a Daniel Bernoulli, were rapt almost into ecstasy by a single atom, when they observed how its properties, and only such properties, fitted it for making part of a world, which

Unwearied, and from day to day,
Should its CREATOR'S power display.

Let the unhappy La Place consider these properties, which ensure the permanency of the solar system through ages of ages, as proofs of fatalism, as qualities essential to matter. But this Gallic torch effaces the bloom of life from the universe, the expression of the Supreme Mind which shines from within; and it spreads over the countenance of Nature the ghastly paleness of universal death. But let us Britons rather follow the example of our illustrious countryman, and solace ourselves with every discovery which tends to quicken our perception of Nature's animated charms. Let us listen to the conjectures of him who had already discovered so many, and who endeavoured to remove the veil which concealed the rest.

21
Moving powers are inherent in all matter. Newton's conjecture improved by Boscovich.

Newton, in his maturity of judgment, after having collected much information from his unwearied experiments in magnetism, in chemistry, in optics, &c. said, that "he strongly suspected, that, in the same manner as the bodies of the solar system were connected by gravitation, so the particles of sublunary bodies were connected together, and affected each other, by means of forces which acted at small, and, in many cases, insensible distances; producing the phenomena of cohesion, in all its forms of hardness, elasticity, ductility, softness, fluidity, by which their mechanical actions on each other were modified and regulated." Father Boscovich, one of the first mathematicians of Europe, was the first who gave this conjecture of Newton's the attention that it so highly deserved. Other writers indeed, such as Keill, Freund, Boerhaave, &c. took occasional notice of it, and even made some use of it in their attempts to explain some complicated phenomena of nature. But they were so careless in their employment of Newton's conjecture, so completely neglected his cautious manner of proceeding, indulged to wantonly in hypothetical assumptions, and reasoned so falsely from them, that they brought his conjecture into discredit. Boscovich, on the contrary, copied Newton with care, and secured his progress as he advanced by the aid of geometry; establishing a set of uncontrovertible propositions, which must be the inevitable results of the premises adopted by him. He then proceeded to compare these with the phenomena of nature; and he shews that the coincidence is as complete as can be desired. All this is done in his *Theoria Philosophiæ Naturalis*, first published at Vienna in 1759. We have given a very short account of it in the article BOSCOVICH, *Suppl.*; but it hardly goes beyond the enunciation of the general principles, and the indication

of its applicability to the purposes intended. His application of bodies, is peculiarly satisfactory. But as the work is written chiefly with the view of gaining the approbation of persons well instructed in natural philosophy, it can hardly be called an elementary work, or be employed for the instruction of persons entering on the study. We shall attempt to explain this important law of mechanism in a way that will give our readers a distinct notion (and, we apprehend, a just one) of the procedure of Nature in all the cases of impulsion *that we can observe*. We hope to do this, by considering the changes of motion produced by moving bodies in a certain series of familiar cases, where the procedure of nature may be distinctly observed, and where it is uniformly conceived by every spectator; and which will gradually lead the mind to those cases where the procedure is not observed with distinctness: but the similarity to the former case is concluded by so fair analogy, that we imagine no person will controvert it. We shall begin by attending to the manner in which two magnets in motion affect each other's motions; a phenomenon that is familiarly known in the general, although, perhaps, few persons have attended to it minutely.

Let us, therefore, suppose two magnets, A and B Plate xxxix. (fig. 1.) equal in weight (in the first instance). Let them be made to float on water, by placing them on pieces of cork. Let them be placed with their north poles touching each other. Let A be held fast, and let B be at liberty to move. We know that it will gradually recede from A, with a motion that would continually accelerate, were it not for the resistance of the water. What is the inference drawn from this appearance? Surely this, that either a moving power, inherent in A, repels B, or that B avoids A, by an evasive power inherent in itself. It is immaterial for our purpose which opinion we adopt. Let us say that A repels B. This admits more concise language than the other. If we prevent this motion of B by means of a very slender spring applied to its remote end, we shall observe that the spring is bent back a little, just as if we were pushing away the magnet gently with the finger; and we observe, that the bending of the spring is so much the greater as B is nearer to A. We can judge of the intensity of the force by which B is actuated, by the bending of the spring.—This force is equal to the weight of any body that will bend the spring to the same degree. This force is analogous, therefore, to the weight, the pressure of gravity, and we may call it a pressure, and measure it by grains weight. Every force that can bend a spring will move a body. This is a well known fact. Therefore it is next to certain, that it is this force which causes B to recede from A; nay, if we compare the motion of B with what *should* result from the action of a force having this very intensity, and varying in the same manner by a change of distance from A, taking in the diminution which the resistance of the water must occasion, we shall find the motions precisely the same. All this can be discovered by DYNAMICS, n° 95, &c. Therefore we must conclude that this, and no other, is the cause of the recess of B.

If, instead of placing B in contact with A, we place it at a distance from it, and push it toward A with an initial velocity, somewhat less than it would have acquired.

Impulsion.

22
Examination of the mutual action of magnets.

Impulsion. quired in that place by its recess from A, we shall find that it will approach A with a motion gradually retarded, till it stop at a small distance from A; and will now recede from it again with an accelerated motion. In short, we shall find that its whole motion to and from A is precisely the same with what results from a similar computation by n^o 95 of DYNAMICS.

The whole of this phenomenon is conceived by every beholder, who has not imbibed some peculiar theory of a stream of impelling fluid, as the indication and effect of a repulsive force exerted by A on B, or of a quality of B, by which it recedes from A.

If now B be held fast, and A be set at liberty, it is observed to be repelled by B, or to recede from B, in the same manner, and with the same force.

Thus, the two magnets appear to affect each other's motions, and are thought, and said, by all to repel each other. The effect appears curious, but excites no farther thought in most minds: it is only the speculatist that begins to suspect that he has not conceived it properly.

Now, let us suppose that B is afloat on the surface of the water, and at rest; and that A is pushed towards it, by a single stroke, causing it to move so moderately that it shall not strike B, but have its motion destroyed by the repulsion before it reaches it; and let us farther suppose, that the initial velocity of A was exactly measured—the fact will be as follows. As soon as A comes within a certain distance of B, its motion begins to be affected; it gradually diminishes, and at length it ceases entirely, and A remains ever after perfectly still. But it is also observed, that in the instant that A slackens its motion, B begins to move; and that it gradually accelerates in its motion, and at last acquires the initial velocity of A, with which it proceeds, till the resistance of the water brings it to rest; perhaps at a considerable distance from A. This experiment is very amusing, and the initial velocity of A may be increased in each succeeding trial, till at last it strikes B. Even then the general appearance remains the same: A is brought to rest and remains at rest, neither retreating nor advancing forward; and B moves off with the initial velocity of A. What we wish to be particularly noticed is, that as long as the initial velocity of A is less than a certain quantity (depending on the strength of the magnets), the motion is communicated to B, or, to express it more cautiously, motion is produced in B, without any thing happening that can get the name of impulsion with propriety. In the ordinary conceptions and language of mankind, impulse always supposes actual contact; and impulsion is equivalent to a blow or a stroke. Both of these are indeed metaphorical terms, as well as impulsion. Perhaps the word “to hit,” expresses this particular case more purely, and it is perhaps without any figure, and is the appropriate word. We do not speak at present of the conception and language of philosophers, but of persons taking an unconcerned view of things, without any intention of speculating farther about the matter.

Appearances perfectly similar are observed in electrified bodies. If we hang two equal bunches of very light downy feathers by two equal linen threads, so as to hang close by each other like pendulums without

Impulsion. touching, and if, after having electrified them so that they repel each other to some distance, we draw one of them, which we shall call A, considerably aside from the perpendicular, and then let it go to swing like a pendulum; we shall observe, that instead of accelerating till it reach the lowest point of its vibration, its motion will be retarded; it will stop entirely when its thread is perpendicular, and will remain at rest. In the mean time, the other bunch B will acquire motion, which will gradually increase till it equal the motion of A in its maximum state; and with this it would proceed for ever, were it not rising like a pendulum in the arch of a circle. The general fact is the same as in the case of the magnets. The moving body is brought to rest, in which state it continues, and the quiescent body moves off with an ultimate velocity, equal to the initial velocity of the other; and all this happens without contact or impulsion, but is produced by the mutual repulsion of the electrified bodies.

If this general fact be compared with what happens in the collision of two billiard balls, it will be found perfectly similar in every respect, but that of the contact and the impulsion, properly so called. The impelling ball is brought to rest, and remains at rest; and the impelled ball moves off with the velocity of the impelling ball.

This being the case, it is plain that we may derive some information from the motion of the magnets, that must greatly assist us in our conceptions of what passes in the rapid, if not instantaneous, production of motion in a billiard ball, by hitting it with another. In the case of the magnets, we perceive, and can discriminate, a progressive train of changes, which terminate in a final change, perfectly similar to the change in the impulsion of the billiard ball. This will justify a very minute attention to, and statement of, all the circumstances.

Let us attend to the process of this operation, and the production of motion in the magnet originally at rest, and the abolition of it in the one originally in motion; and let us reflect on what passes in our minds when we try to explain it to ourselves. The trials mentioned at first, when one magnet was held fast, shew us that each magnet repels or avoids the other, and that this action is found to be equal on both sides, producing equal compression of the spring employed for ascertaining the intensity of this repulsion when the distances are the same. This is the fact. It is no less a fact, that equal moving forces, such as equal pressures must be supposed to be, produce equal changes of motion in their own direction. Therefore, as soon as A comes to such a distance from B that the mutual action takes place, both magnets are affected, and equally affected; that is, equal changes of motion are produced on each, but in opposite directions. The motion of A is diminished, perhaps $\frac{1}{10}$ th part in $\frac{1}{5}$ th of a second, and (let it be carefully remembered) while A passes over a certain space, suppose the 10th of an inch. During this small portion of time, B acquires as much motion as A loses. This is not the motion lost by A. This is inconceivable; for motion is not a thing, but a condition. But it is an *equal degree* of motion. B has passed over a small space during this time, perhaps the 50th part of an inch, with an almost imperceptible motion,

^{Impulsion} motion, that is gradually accelerated from nothing. Since A is moving faster than B, it must still gain upon it; and therefore the mutual repulsion will increase; and in the next roth of a second this force will take another and greater portion of A's original velocity from it, and will add a greater velocity to that already acquired by B. And thus, in every succeeding minute portion of time, the motion of A will be more and more diminished, and that of B as much increased, by the equal, though continually increasing, simultaneous repulsions acting in opposite directions. It is evident, that it is possible that the velocity of A may be so much diminished, and that of B so much increased, that the remaining velocity of A shall be just equal to the acquired velocity of B. Till this happens, the distances of the magnets have been continually diminishing; for A has been moving faster than B, and gaining on it. If the operation of the mutual repulsions could be stopped at this instant, both magnets would move forward for ever with equal velocities.

²⁴ They acquire a common velocity x;

It is of particular importance to know what this common velocity is. This is determined by our previous knowledge, that the magnets repel or avoid each other with equal forces. These forces may vary by a variation of distance; but the force acting on A is always equal and opposite to the force acting at the same time on B. This is the uncontroverted fact (the authority for which shall soon be considered). These equal forces must therefore produce equal and opposite changes of motion. The motion acquired by B is equal to that lost by A. But the magnets being supposed equal, and moving with equal velocities, they have equal quantities of motion. Therefore the motion acquired by B, or that lost by A, is equal to what remains in A; that is, A has lost half of its motion, and therefore half of its velocity; or the common velocity is half of the primitive velocity of A.

It was for the sake of a somewhat easier discussion that we supposed the magnets to be of equal weights. But it is almost equally easy to ascertain what this common velocity will be in any other proportion of the quantities of matter in A and B. It is a matter of unexcepted experience, that whatever be the weight or strength of two magnets, their actions on each other are always equal. Therefore the simultaneous force must always produce equal changes of motion in the two bodies. But the change of motion is expressed by the product of the quantity of matter and the change of velocity. Therefore let A and B represent the quantities of matter in the magnets; and let *a* be the primitive velocity of A, and *x* the velocity which obtains when both are moving with one velocity. The velocity lost by A is $a - x$. Therefore we must have $Bx = \frac{A \times a}{A + B} - x$, and $x = \frac{Aa}{A + B}$. The common velocity is therefore obtained by dividing the primitive quantity of motion by the sum of the quantities of matter.

²⁵ Namely, $x = \frac{A \times a}{A + B}$

This may be conceived more compendiously in another way. Since B acquires as much motion as A loses, the whole quantity of motion is the same as before: Therefore the common velocity must be had by dividing this quantity of motion by the whole quantity of matter. But we wished to make the reader keep his

attention fixed on the steps of procedure, and see the ^{Impulsion.} connection of each with the causes.

We shall find that this period of the whole process, namely, the moment when both bodies have acquired a common velocity, and the precise magnitude of this velocity, are points of peculiar importance in the doctrine of impulsion; indeed they almost comprehend the whole of it.

But this is a state that cannot continue for a moment in the example before us. The repulsive or evasive forces are still acting on both magnets, and still diminish the motion of A, and equally increase the motion of B. Therefore the velocity of A, in the very next moment, must be less than that of B; and B has, during this moment, gained on A, or has removed farther from it. This continues; A is still retarded, and B is accelerated; and therefore gains more and more upon A, or separates farther and farther from it. This must continue as long as the mutual repulsions are supposed to act. If we suppose that the *sensible* action of these forces is limited to some determinate distance, the mutual action will cease when B has got to that distance before A. We may call it *the inactive distance*. After this, A and B will proceed with the velocities which they have at that instant. Let us inquire into these final velocities; and thus complete our acquaintance with the process.

²⁶ But this does not continue, and the magnets separate.

We see (and it is important) that the magnets are in their state of greatest proximity at the instant of their moving with a common velocity, and that after this they gradually separate, till they are again at their inactive distance. During this separation they attain distances from each other equal to what they had during the period of their mutual approach. At these distances the repulsions are the same as before, and act in the same direction. Therefore, in each moment of separation, and at each distance, A sustains the same diminution, and B gets the same augmentation of its motion, as when they were at the same distance in the period of their mutual approach. The sums total, therefore, of these equal augmentations and diminutions must be equal to the augmentation and diminution during the approach. Therefore the whole diminution of A's motion must be double of the diminution sustained during the approach; and the whole augmentation of B's motion must, in like manner, be double of that acquired during the approach of A. Hence we easily see, that when the magnets are supposed equal, A must be brought to rest; for in the period of approach it had lost half of its velocity. It must now have lost the whole. For similar reasons B must finally acquire the primitive velocity of A; for in the instant of greatest proximity, it had acquired the half of it.

²⁷ The common velocity is attained at the instant of nearest approach.

Thus we see that the equal mutual repulsions are precisely adequate to the production of the changes of motion that are really observed; and must therefore be admitted as the immediate causes of these changes.

²⁸ Repulsion is a cause adequate to the observed effect.

It is equally easy to ascertain the final velocities when the magnets are of unequal sizes; for the equality of their mutual repulsions is not affected by any inequality of their magnitudes. Their separations, and the changes of motion during these separations, will be the same with their approaches and the corresponding changes of motion; and the whole change on each will be double of the change sustained at the instant of greatest

²⁹ Effect when the magnets are unequal.

Impulſion. greateſt proximity and common velocity, Hence we learn that the final velocity of B is 2α , or $\frac{2Aa}{A+B}$; and the final velocity of A is $\frac{A-B \times a}{A+B}$. For the primitive velocity of A being a , and the common velocity, in the inſtant of neareſt approach being $\frac{Aa}{A+B}$, the loſs of velocity is $a - \frac{Aa}{A+B} = \frac{Aa + Ba - Aa}{A+B} = \frac{Ba}{A+B}$. Therefore the final loſs of velocity is $\frac{2Ba}{A+B}$, and the remaining final velocity is $a - \frac{2Ba}{A+B} = \frac{Aa + Ba - 2Ba}{A+B} = \frac{A-B \times a}{A+B}$.

³⁰ II. Caſe. Both magnets in motion in one direction. Let us, in the next place, ſee what will be the reſult when both of the magnets are in motion at the beginning of their mutual action. And, firſt, let both move in one direction. Let A, moving with the velocity a , overtake B, moving in the ſame direction with the velocity b , leſs than a . Moreover, let the velocities a and b be ſuch, that their differences $a - b$ is ſomewhat leſs than the ſum of the velocities α and β , which the mutual repulſions of the magnets would generate in them, if the magnets were placed in contact, and allowed to recede from each other till they get beyond their acting diſtance.

Theſe things being premifed, let the magnets be let in motion in the ſame direction with the above-mentioned velocities a and b . The magnet A muſt gain on B, and at laſt come ſo near it, that the mutual repulſions begin to act on both. It is plain, that the motion of A will be diminiſhed, and that of B increaſed, by equal quantities, during every minute portion of the time of their mutual action. It is alſo evident, that the velocity of A may be ſo much diminiſhed, and that of B ſo much increaſed, that they ſhall be rendered equal. Alſo this will happen before the magnets touch one another; becauſe the original difference of their quantities of motion has been ſuppoſed leſs than the motion which the repulſive forces are able to generate or extinguiſh, by acting on them through the whole diſtance which gives occaſion to their action. Therefore the difference of the velocities is leſs than the ſum of the velocity α , which the mutual repulſion can take from A, and the velocity β , which it can give at the ſame time to B. The magnets will gradually approach, and the mutual repulſions, and conſequent diminiſhment of A's, and augmentation of B's motion, will gradually increaſe, till the ſum of α and β is juſt equal to the difference of a and b ; that is, till the bodies are moving with one velocity. If the mutual repulſions were annihilated at this inſtant, the bodies would move forward with this common velocity. What this is we determine with great facility, as we did in the former caſe: Becauſe the repulſions produce equal and oppoſite changes of motion in the magnets, as much is taken from $A \times a$ as is added to $B \times b$; and the ſum of $A \times a$, and $B \times b$, is equal to the ſum of $A \times \alpha$ and $B \times \alpha$, or $\frac{Aa + Bb}{A+B} \times \alpha = A \times \alpha + B \times \alpha$, and $\alpha = \frac{Aa + Bb}{A+B}$.

Therefore the common velocity is had by dividing the ſum of the primitive quantities of motion by the ſum of the quantities of matter.

But the repulſive forces continue to act as in the former caſe. The motion of A is ſtill more diminiſhed, and that of B augmented: Therefore the velocity of B muſt now exceed the velocity of A, and the magnets muſt ſeparate. Reaſoning in the ſame way as in the former caſe, it is evident that the mutual action does not ceaſe till the magnets have ſeparated to their inactive diſtance from each other, and that the whole change of motion in each is double of the change that it had ſuſtained when they were in their greateſt proximity, and moving with a common velocity. Theſe conſiderations enable us to aſcertain the final ſtate of each. The common velocity is $\frac{Aa + Bb}{A+B}$. Therefore the change made on the velocity of A, at the inſtant of greateſt proximity, is $a - \frac{Aa + Bb}{A+B}$, or =

$\frac{B \times a - b}{A+B}$, and the final velocity of A is $a - \frac{2B \times a - b}{A+B}$. In like manner, the change produced on the velocity of B is = $\frac{Aa + Bb}{A+B} - b$, or = +

$\frac{A \times a - b}{A+B}$, and the final velocity of B is $b + \frac{2A \times a - b}{A+B}$. We may alſo obtain the final velocity of each, by taking its initial velocity from twice the common velocity.

If, in this example of two magnets in motion, we ſuppoſe them of equal weight, we ſhall find that they will finally proceed with exchanged velocities. For when $A = B$, it is plain that $a - \frac{2B \times a - b}{A+B}$ is = $a - 1 \times a - b$, = $a - a + b$, = b : and $b + \frac{2A \times a - b}{A+B}$ is = $b + 1 \times a - b$, = $b + a - b$, = a . This caſe is eaſily ſubjected to experiment, and will be found fully confirmed, if we take into account the retardations occaſioned by the reſiſtance of the water to the motions.

Let us, in the next place, ſuppoſe the magnets to be moving in oppoſite directions with the velocities a and b ; and (in order that the magnets may not ſtrike each other) let the ſum of a and b be leſs than the ſum of α and β , which the repulſions of the magnets would produce by repelling them from contact to their inactive diſtance.

As ſoon as the magnets arrive at their acting diſtance, their mutual and equal repulſions immediately begin to diminiſh both of their motions; and in any minute portion of the period of their approach, equal quantities of motion are taken from each. It is evident, that if the primitive quantities of motion have been equal; that is, if A and B have been moving with velocities reciprocally proportional to their quantities of matter, then, when the motion of one of them has been annihilated by their mutual repulſion, the motion of the other will be

³¹ Common velocity = $\frac{Aa + Bb}{A+B}$ but the magnets ſeparate, and the change is doubled in each.

³¹ Magnets moving in oppoſite directions.

^{Impulsion.} be destroyed at the same time, and both will be brought to rest. Were the repulsions annihilated at this instant, they would remain at rest. But because those forces continue their actions, the magnets will separate again, regaining, at every distance, the velocity which they had, when at that distance, during their mutual approach; and when they have reached their inactive distance, they will have regained each its original momentum and velocity, but in the opposite direction. This needs no farther comment; but must be kept in mind, because this case has a precise counterpart in the collision of solid bodies, meeting each other in opposite directions with equal momenta. But if the momentum of one exceed that of the other, thus, if $A \times a$ be greater than $B \times b$, then, when the magnet B is brought to rest, A has still a momentum remaining equal to $Aa - Bb$. Having therefore a certain velocity, while B has none, it must approach still nearer to B, and a still greater repulsion will be exerted on B than if A had also been brought to rest, but still repelling B. Since B is now acquiring motion in the direction opposite to its former motion, and A is still losing motion, a time must come when the motion of A is so much diminished, and that of B so much augmented, that they are moving with a common velocity in the direction of A's primitive motion. The reasoning employed in the foregoing examples shew us, that, in the present case also, this state of common velocity is also the state of the greatest proximity, and that the magnets separate again, till they attain their distance of inaction, and that the total change in each is double of what it was in their state of greatest proximity.

³² Common velocity = $\frac{Aa - Bb}{A + B}$ but the change is doubled by the subsequent separation.

To find this common velocity, recollect, that when the momentum of B was extinguished, that of A was still $Aa - Bb$. From what has been already said on the other cases, we know that when the common velocity obtains, the whole momenta are still equal to $Aa - Bb$. Therefore the common velocity x must be
$$= \frac{Aa - Bb}{A + B}$$

The velocity lost by A must therefore be $a - \frac{Aa - Bb}{A + B}$, and the final velocity will be $a - \frac{2B \times a + b}{A + B}$. The final motion of A will be in the same direction as at first, if a be greater than $\frac{2Ba + b}{A + B}$, otherwise it will be in the opposite direction.

In like manner, the change of velocity in B is $b + \frac{Aa - Bb}{A + B}$, because the former velocity b is destroyed, and the new velocity is $\frac{Aa - Bb}{A + B}$ in the opposite direction. This is $= \frac{A \times a + b}{A + B}$, and the final velocity of B is $b - \frac{2A \times a + b}{A + B}$.

³³ The changes of motion in the magnets are similar to those in the collision of bodies.

Thus we have shewn, in the case of magnets acting on each other by repulsive forces, or actuated by forces equivalent to repulsive forces, how changes of motion are produced, which have a great resemblance to those which are seen in the collision of solid bodies.

The motions which obtain in the instant of greatest proximity are precisely similar to what are observed in the collision of unelastic bodies. Their common velocity after collision is always $= \frac{Aa + Bb}{A + B}$, or $= \frac{Aa - Bb}{A + B}$, according as the bodies were moving in the same or in opposite directions. The final motions of the magnets are also precisely similar to what are observed in the collision of perfectly elastic bodies. We took the instance of magnets, because the object is familiar; but we can substitute, in imagination, an abstract repulsive force in place of magnetism, and we can assign it any intensity, and any law and limits of action we please. We can imagine it so powerful, that although its action be limited to a very small, and even insensible distance, it shall always reduce the meeting bodies to a common velocity before they come into actual contact; and therefore without any real impulsion, as impulsion is commonly conceived.

^{Impulsion.}

There are some farther general observations that may be made on those motions which are of importance.

1. We see that the changes of motion, and consequently the actions, are dependent on the relative motions only, whatever the absolute motions may be: For proportional changes are always as $a - b$ when the bodies are moving in one direction, and as $a + b$ when they are moving in opposite directions. Now $a \pm b$ is the relative motion.

³⁴ These changes are proportional to the relative motion.

2. The change of velocity in each of the two bodies is inversely as its quantity of matter, or is proportional to the quantity of matter in the other body. The changes in A and B are $\frac{B \times a \pm b}{A + B}$ and $\frac{A \times a \pm b}{A + B}$.

³⁵ And reciprocally as the quantities of matter.

The changing forces being equal on both sides, produce equal changes in the quantities of motion; and therefore produce changes of velocity that are inversely as the quantities of matter.

3. During the whole process, the sum of the momenta, or quantities of motion, remains the same, if the bodies are moving in one direction: if they are moving in opposite directions, it is the difference of momenta that remains the same; for in every instant of the process equal changes of momentum are made in opposite directions. When the motions are in the same direction, as much is taken from the one as is added to the other; and therefore the sum remains unchanged. When the motions are in opposite directions, equal quantities are taken from both; and therefore the difference remains unchanged. This is called the CONSERVATIO MOMENTORUM; and it is usually enunciated by saying, that the quantity of motion, estimated in one direction, is not changed by the equal and opposite actions of the bodies. This is a particular case of a general law affirmed by Des Cartes, that the quantity of motion in the universe remains always the same when estimated in any one direction.

³⁶ CONSERVATIO MOMENTORUM.

4. When the whole process is completed, the sum of the products made by multiplying each body by the square of its final velocity, is equal to the sum of the products made by multiplying each body into the square of its initial velocity. For when the process is completed, the two bodies are at the same distance from each other as when the mutual action began. There-

³⁷ CONSERVATIO VIRIUM.

Impulsion. Such is the fact; and we shall find it of importance in the great debate about the force of moving bodies. **Physical cause of this loss.** Let us inquire into the physical or mechanical cause of it. In the moment of common velocity, the bodies are nearer to each other than they are at the beginning and at the end of their mutual action. Therefore (when they are moving in one direction) the body A, which follows, has been retarded through a space which is greater than the space along which the preceding body B has been accelerated. But, because the simultaneous forces acting on the bodies along these unequal spaces are always equal, the area which measures the diminution of the square of A's velocity (DYNAMICS, n° 95.) must exceed the area which expresses the augmentation of the square of B's velocity, and there must be a loss of *vires viva*. Now, we learned above, that the mutual action is the same when the relative velocity is the same; and therefore the approximation, which is the occasion of this action, must be the same. And it is demonstrated in DYNAMICS, n° 95. that the area, whose abscissa is the space described, and ordinates the forces, expresses the square of the generated or extinguished velocity. This is evidently the relative velocity of the bodies, because they are brought to a common velocity in the instant of greatest proximity; that is, their relative velocity is destroyed.

39 The motion of the common centre of gravity is not changed by the mutual action.

6. During the whole process, the common centre of position or gravity (A) is moving uniformly with the

velocity $\frac{Aa \pm Bb}{A+B}$. For the motion of the centre of

position is the average of the motion of every particle of matter in both bodies. Aa is the sum of the motions of every particle of matter in A, and Bb is the sum of the motions of every particle in B, before the mutual actions began. Therefore $Aa + Bb$ is the whole motions when the bodies are moving in the same direction with their different velocities. The number of particles is $A + B$: Therefore, if the whole motions be equally divided among all the particles, the velocity of each must be $\frac{Aa + Bb}{A+B}$. This is the average motion, or the motion of the centre of position, deduced from the notion we wish to impress of the character of this centre, as the index of the position and motion of any assemblage of matter. This velocity may be deduced more easily from its geometrical property. It is a point so situated between A and B, that its distance from each is reciprocally proportional to the quantities of matter in A and B, as is well known of the centre of gravity. It is equally plain, that when the bodies are moving in opposite directions, the average velocity x must be $= \frac{Aa - Bb}{A+B}$. Thus we see, that the motion of the centre of position, before the magnets have begun to act on each other, is the same

with its motion when their mutual repulsion is the greatest; namely, at the moment of their greatest vicinity. It has continued the same during the whole process: For we have already seen, that the sum or difference of the momenta, or $Aa \pm Bb$, remained always

the same; consequently $\frac{Aa \pm Bb}{A+B}$, or x , the motion

of the centre, remains always the same. Therefore the proposition is demonstrated. It is, indeed, a truth much more general than appears in the present instance. *If any number of bodies be moving with any velocities, and in any directions, the motion of the centre of position is not affected by their mutual, equal, and opposite, actions on each other.*

7. During the whole motion, the motion of the bodies relative to each other, is to the motion of one of them, relative to the centre of position, as the sum of the bodies is to the other body: For when they were moving with a common velocity, this velocity was the same with that of the centre; and they are then at rest, relative to each other, and relative to the centre. And because their distances from the centre are inversely as the bodies, their changes of distance, that is, their motions relative to the centre, are in the same proportion; and the sum of their motions relative to the centre is the same with their motions relative to each other. Therefore $A + B : A = a - b$: motion of B relative to the centre. Indeed we saw, that in their mutual action,

the change of B's motion was $= \frac{A \times a - b}{A+B}$, and the

change of A's motion was $= \frac{B \times a - b}{A+B}$.

Hence we learn, that while the centre moves uniformly, the bodies approach it, and then recede from it, with velocities reciprocally proportional to their quantities of matter. This will be found a very useful corollary. We may also see that their final velocity of mutual recess is equal to that of their first approach, or their relative motions are the same in quantity after the action is over as before it began, but in opposite directions.

All these general facts, which are distinctly appreciable, and very perceivable, in this example of magnets, or electrified bodies, are equally appreciable in all cases of mutual repulsions, however strong these may be; and although the space through which they are exerted should be so small as to elude observation, and though the whole process should be completed in an insensible moment of time.

It scarcely needs any comment to make it clear that the very same changes of motion must take place, if a solid body A should come up to another solid body B, at rest, or moving more slowly in the same direction, or moving in the opposite direction; provided that there be a spring interposed between them, which may hinder

(A) See the article POSITION in this Supplement; where it will be demonstrated, that the centre of gravity (determined in the usual manner) is the point by whose situation and motion we estimate with the greatest propriety the situation and motion of the assemblage, of which it is the centre: it is therefore called the CENTRE OF POSITION. The reader is only desired at present to recollect, that the centre of gravity, or position of two bodies, is situated in the line joining their centres; and that its distance from each is inversely as their quantities of matter; and that the distance and motion of the centre is the medium or average of all the distances or motions.

Impulsion. A from striking B; for, as soon as A touches the spring, it begins to press it against B, and, therefore, to compress the spring. It cannot carry the spring before it, without the spring's pushing B before it. Pressure on B is required for this purpose. This is supplied by that natural power which we call elasticity, which is inherent in the spring; whether it be in motion or at rest. It is not in *action*, but in *capacity, faculty, capability, power*, or by whatever name we may choose to express the possession. The occasion required for its exertion is compression. This is furnished by the motion of A; for A cannot advance without compressing it. This inherent force of the spring is *known* to act with perfect equality at both ends, in opposite directions. It exerts equal and opposite pressures on A and on B; it diminishes the motion of A, and equally augments the motion of B (if both are moving that way). A is retarded, and B is accelerated; A is still moving faster than B; and therefore the compression and the consequent reaction of the spring increases, and still more retards A and accelerates B. After some time, both bodies, with the spring compressed between them, are moving with equal velocities; the spring, however, is strongly reacting on both, and must now cause them to separate; still retarding A, and accelerating B—They must separate more and more, till the spring regain its quiescent form, and its elastic reaction cease entirely. During its restitution, its pressures are the same as during its compression, therefore, the whole change produced on each of the bodies must be double of what it was when the spring was in its state of greatest compression, and the bodies were moving with a common velocity. In short, the whole process in this example must be precisely similar to that of the magnets in every circumstance relating to the changes of motion in A and B. The common velocity must be

$$= \frac{A a \pm B b}{A + B}.$$

The final velocity of A must be $= a - \frac{2 B a \pm b}{A + B}$, and that of B must be $= b + \frac{2 A a \pm b}{A + B}$.

The motion of the common centre must be unaffected by the action of the spring, and the motion of each body, relative to the centre, must be reciprocally as its quantity of matter, &c. &c.

We apprehend that this process can scarcely be called impulsion; A has not struck B. The changes of motion can scarcely be ascribed to forces inherent in A or B, in consequence of their being in motion. Any person, not already warped by a theory, will (we think) ascribe them to a force inherent in the spring; inherent in it, whether at rest or in motion, and only requiring a *continued* compression as the proper opportunity for its continued exertion. This spring may be supposed to make a part of B, or of A, or of both; and then, indeed, the force may be said to be inherent in either, or in both. But it is not the peculiar force inherent in motion, or in moving bodies *only*—it is the force of *elasticity*, inherent in part of the body, but requiring a *continued compression* for the production of a *continued repulsion*. The effect of this reaction is modified by the very occasion of the compression. This may be the elasticity of another spring. In this case it will only compress that spring.—It may be the advance of a body in motion; the reaction produces a retarda-

tion of that motion; it may be the obstacle of a quiescent body—it will give it motion; or, it may be the abstraction by a body moving more slowly away than the spring is pressed forward—it will accelerate that motion. Thus, in all these cases, we cannot help distinguishing the immediate cause of these changes of motion from the supposed force of a moving body. Nay, the process of motion is similar, even when we suppose that the spring is not a thing external to the body, although attached to it; but that the whole body, or both bodies, are springy, elastic, and therefore compressible. As soon as the bodies come into sensible contact, compression *must* begin; for we may suppose the bodies to be two balls, which will therefore touch only in one point. The mutual pressure, which is necessary in order to produce the retardation of A, and the acceleration of B, is exerted only on the foremost particle of A, and the hindmost particle B; but no atom of matter can be put in motion, or have its motion any way changed, unless it be acted on by an adequate force. The force urging any individual particle, must be precisely competent to the production of the very change of motion which obtains in that particle. Except the two particles which come into contact in the collision, all the other particles are immediately actuated by the forces which connect them with each other; and the force acting on any one is generally compounded of many forces which connect that particle with those adjoining. Therefore, when A overtakes B, the foremost particle of A is immediately retarded—the particles behind it would move forward, if their mutual connection were dissolved in that instant; but, this remaining, they only approach nearer to the foremost striking particles, and thus make a compression, which gives occasion for the inherent elasticity to exert itself, and, by its reaction, retard the following particles. Thus each stratum (so to conceive it), continuing in motion, makes a compression, which occasions the elasticity to react, and, by reacting, to retard the stratum immediately behind it. This happens in succession: the compression and elastic reaction begin in the anterior stratum, and take place in succession backward, and the whole body gets into a state of compression. Things happen in the same manner in B, but in the contrary direction, the foremost strata being the last which are compressed. All this is done in an instant (as we commonly, but inaccurately speak), that is, in a very small and insensible moment of time; but in this moment there is the same gradual compression, increase of mutual action, greatest compression, common velocity, subsequent restitution, and final separation, as in the case of bodies with a slender spring interposed, or even in the case of the mutually repelling magnets. In all the cases, the changes of motion are produced by the elasticity or the repulsion, and not by the transfusion of the force of motion. The changing force is indeed inherent in the bodies, but not because they are in motion; the use of the motion is to give occasion, by continued compression, for the continued operation of the inherent elasticity. The whole process may be very distinctly viewed, by making use of bodies of small firmness, such as foot-balls, or blown bladders. If blown bladders are used, each loaded with sand, or something that will require more force, and consequently

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The changes of motion are produced by the inherent forces which connect the particles.

44
Internal process of change through the substance of each body.

Impulsion. consequently more compression to impel it forward; we shall observe the compression of both to be very considerable, and that a very sensible time elapses during the process of collision. This may even be observed very distinctly in a foot-ball, which is always seen to rest a little on the toe before it flies off by the stroke. When one foot-ball is strongly driven against another, they plainly adhere together for some time, and then the stricken ball flies off.

If we return to the example of the two balls with the spring interposed, we may make some farther useful observations. When the spring is in its state of greatest compression, and the balls are moving with a common velocity, we can suppose that the spring is arrested in that situation by a catch. It is evident that the two bodies will now proceed in contact with this velocity,

which we have shewn to be $= \frac{A a \pm B b}{A + B}$.

45
Nature of
imperfect
elasticity.

Now, in the constitution of such masses of tangible matter as we have the opportunity of subjecting to our experiments, we find a state of aggregation which very much resembles this. Some bodies are almost perfectly elastic, that is, when their shape is changed by external pressure; and that pressure is removed, they recover their former shape completely, and they recover it with great promptitude. Glass, ivory, hard steel, are of this kind. But most bodies either do not recover it completely, or they recover it very slowly—some hardly recover it at all. A rod of iron will, when considerably bent, not nearly recover its shape; a rod of lead still less; and a rod of soft clay will hardly recover it in any degree. These, however, are but gradations of one and the same quality: if the quietest form of a body is very little disturbed, it will recover it again. Thus, a common soft iron wire of N^o 6. and 12 inches long, if twisted once round, will return completely to its original form, and will allow this to be repeated for ever; but if it be twisted 1½ turns, it will untwist only 1; and in this new form, it will twist and untwist one turn as often as we please. Even a rod of soft clay, ¼th of an inch in diameter, and 7 feet long, will bear one twist as often as we please; but if twisted 4 times, will untwist itself only one turn, and will do this as often as we choose. In short, it appears that the particles of bodies, usually called unelastic, will admit a small change of distance or situation, and will recover it again, exhibiting perfect elasticity, in opposition to very small forces; but if they are forced too far from this situation, they have no tendency to return to it completely, but find intermediate situations, in which they have the very same connections with the surrounding particles; and in this new situation, they can again exhibit the same perfect elasticity, in opposition to very small forces. Mr Coulomb conceives such bodies to consist of elastic particles: they manifest perfect elasticity, so long as the forces employed to change their shape do not remove the particles from their present contacts; but if they are removed from these, they slide on to other situations, where they again exhibit the same appearances. To understand this fully, the reader may consult the article BOSCOVICH of this Supplement—The fact is sufficient for our present purpose. Now, in this variable constitution, where the particles may take a thousand differ-

ent situations, and still cohere, it is plain, that when a body has been dimpled by compression, the particles have nothing to bring them back to their first situation when the compressing force is removed: the utmost elasticity to be expected, is that which will not extend to one shift of situation; therefore, the restitution is altogether insensible. This is the case with all soft bodies, such as clay—the same quality is manifested in all ductile bodies, such as lead, soft iron and steel, soft copper, soft gold.

Now let one of these bodies strike another. The compression, or the sliding of the particles over each other, requires force, or mutual pressure—This being accompanied by a reaction perfectly equal, must operate, during the compression, precisely as the equal repulsive forces did. It will take as much momentum from A as it gives to B; so that $A a \pm B b$ will remain invariably the same, and a common velocity will at last ob-

tain, $= \frac{A a \pm B b}{A + B}$. The compression can proceed no farther, and the two bodies must now proceed in contact with this velocity.

And thus we see, that in the case of compressible, but unelastic bodies, the changes of motion are produced by the cohesive forces inherent in the bodies; but not inherent in them because they are in motion. We see clearly in this way, how the pendulum used by Robins and his followers gave a true measure of the velocity of the ball. All the while that it was penetrating into the pendulum, overcoming the cohesion as it went in, this cohesion was acting equally in both directions. While the fibre was breaking, it was pulling both ways; it was holding back the ball which was breaking it, and it was pulling forward the parts to which it still adhered; and when it broke at last, it had produced equal effects on the ball and on the pendulum in opposite directions. By such a process, the pendulum was gradually accelerated, and acquired its utmost velocity when the ball had ceased to penetrate.

Therefore, this velocity must be $= \frac{A a}{A + pend^m}$.

What should we now expect to happen in the collision of bodies? Such bodies as exhibit perfect elasticity, when examined by bending, or other trials, should have their motions changed precisely like the magnets, or bodies which repel or avoid each other at sensible distances. Bodies which exhibit no elasticity whatever, should continue in contact after collision. The common velocity in these should be

$\frac{A a \pm B b}{A + B}$. The perfectly elastic bodies should sustain

changes of motion which are precisely double of the changes sustained by unelastic bodies, and should separate after collision with a relative velocity of recess or separation, precisely equal to their relative velocity of mutual approach. And bodies possessing imperfect elasticity, should sustain changes of motion which differ from the changes on unelastic bodies, precisely in proportion to the degree of elasticity which they are known to possess. And, lastly, if the changes of motion which obtain in the collision of bodies, are precisely those which would result from the operation of those inherent forces

Impulsion forces of elasticity and cohesion, NO OTHER FORCE WHATEVER CONCURS IN THEIR PRODUCTION: For we know that those forces *do operate* the collision; we see the compression and restitution which are their effective causes, and their immediate effects. If any other force were superadded, we should see its effects also, and the motions would be different from what they are.

Now the fact is, that *we have never seen a body that is not, in some degree, compressible*. It has not pleased the Almighty Creator to make any such here below. Assuredly He has not found such to be of use for the purposes He had in view in this our sublunary world. We know of no body that is perfectly unchangeable in its shape and dimensions. It is therefore no loss whatever to us, although we should not be able to say *a priori* what their motions will be in collision. We cannot even fairly guess them, by reasoning from what we observe in other bodies: For it is just as likely that their motions may resemble those of perfectly elastic bodies as those of unelastic bodies; for we find that bodies of the most extreme hardness are generally highly elastic. Diamond, crystal, agate, quartz, and such like, are the most elastic bodies we know. Philosophers, however, rather think that the motions of perfectly hard bodies will resemble those of unelastic bodies; because elasticity supposes compression. We do not pretend to say with confidence, what would be the motion of a single atom of matter (which cannot admit of compression) which is hit by another in motion. We see all the particles of terrestrial matter connected with each other by certain modifications of the general force of cohesion, so as to produce various forms of aggregation; such as aerial fluidity, liquid fluidity, rigidity, softness, ductility, firmness or hardness; all of which are combined with more or less elasticity. These tangible forms result from certain positive properties of the material atoms of which the particles are composed; and, in all the cases which come under our observation, these properties produce pressures of one kind or another; all of which are moving forces. They are inherent in the particles and atoms; therefore when such atoms are in motion, these forces are in a condition which affords occasion for a *continuation* of this pressure that is competent to the production of motion in another particle. But what would be the event of the meeting of atoms divested of such forces, we profess not to know, or even to conceive.

47
The observed effects of collision are perfectly conformable to the propositions now established.

The fact also is, that all the changes of motion, commonly called impulsions, *which have been observed*, are precisely such as have been described. Unelastic bodies proceed in contact with the velocity $\frac{Aa \pm Bb}{A+B}$. Perfectly elastic bodies separate after collision, and each sustains double of the change that is sustained by an unelastic body. Bodies of imperfect elasticity differ from the two simple cases, precisely in the proportion of the elasticity discoverable by other trials. The mutual actions are observed to be in the proportion of their relative motions, whatever the real motions may be. For not only are the changes of progressive motion exactly in this proportion, but the compressions and changes of figure, which we consider as the immediate occasions of those actions, are also observed to be in the same propor-

tions, *in all cases that we can observe and measure with accuracy*. All these things can be ascertained with great precision by means of the collision of pendulous bodies in the way pointed out by Sir Christopher Wren (a method attributed by the French to their countryman Maiotte, but really invented by Wren, and exhibited to the Royal Society of London the week after he communicated his theory of impulsion).

We must also infer from these facts, that the actions of bodies on each other are mutual, equal, and opposite. This is really an inference from the phenomena, and not an original or first principle of reasoning. The contrary is conceivable, and therefore not absurd. In the same way that we can conceive a magnet repelling iron, without imagining that the iron repels the magnet, we may conceive a golden ball capable of impelling a leaden ball before it, without conceiving that the leaden ball will impel the golden ball. We do not find this easy indeed; because the contrary is so familiar, that the one idea instantly brings the other along with it. We apprehend it to be impossible to demonstrate, that a leaden ball will not stop as soon as it hits the golden ball, or *vice versa*. But all our experience shews us, that the pressures exerted in contact are mutual, equal, and opposite. The same thing is observed in the forces which connect the parts of bodies. A quantity of sand or water balanced in a scale will remain in equilibrio in whatever way it is stirred about; its parts always exert the same pressure on the scale: so does a body suspended by a string or resting on the scale, by whatever points it is supported. This could not be if the particles did not exert mutual and equal forces; nor could the phenomena called impulsions be what they are, if the pressures occasioned between the particles by the compressions and dilatations were not mutual and equal. This law of action and reaction must be admitted as universal, though contingent, like gravity. Doubtless it results from the properties which it has pleased the great Artist to give to the matter of which He has formed this world. There is one way in which we can conceive, most distinctly, how this may be a universal property of matter. If we grant the reality of attractions and repulsions *e distant*, and suppose that every primary atom of matter is precisely similar to every other atom in all its properties, and that this assemblage of properties constitutes it a material atom; it follows, that every atom exerts the same attractions and repulsions, or has the same uniting and evasive tendencies, and then the law of action and equal reaction follows of course. This is surely the very notion that any person is disposed to entertain of the matter. And if mechanical force and mobility are the qualities which distinguish what is material from mind or other immaterial substances, the law of equal and contrary reaction seems nearly allied to the class of first principles.

Of all the phenomena that indicate this perfect equality of action and reaction, the most susceptible of accurate examination is the sameness or equality of action when the relative motions are equal. Now there is no phenomenon more certain than this. In consequence of the rotation of the earth round its axis, and its revolution round the sun, it is plain that all our experiments and observations are on relative motions only. Now, we not only find that the actions of two bodies subjected

48
Extensive proof of the universality of equal action and reaction.

Impulsion. ted to experiment are equal when the relative motions are equal, but we find that all our measures of action on a single body are proportional to the apparent motions which they produce. It requires precisely the same force to impel a ball eastward, westward, south, or north, at 12, or 3, or 6, or 9 o'clock: yet the real motions are immensely different in all these cases, and it is only the relative motions that have the proportions which we observe. Another very important point deducible from our experiments is, that the same *pressure* produces the same change of motion, whatever may be the velocity. We know this by observing, that when the mutual dimpling or compression is the same, the change of motion is the same, whatever be the hour of the day. This could not be if it required a greater pressure to change the velocity 100000 into 100001, than to change the velocity 1 into the velocity 2. Yet this is one of Leibnitz's great metaphysical arguments for proving that the force accumulated, and now inherent, in a moving body, is proportional to the square of its velocity. We beg that this may be kept in remembrance.

It must be granted, that what we have already said on the subject of impulsion may be called an *explanation*; for it deduces the phenomena from general and unquestionable principles, and from acknowledged laws of Nature. The only principle used is, that a moving force is indicated, characterised, and measured, by the motion which it produces. It is an acknowledged law of Nature, that pressures are moving forces; also, that moving forces appear in cases where we observe neither pressures nor impulsions, and which we call repulsions or evasive tendencies; that these are mutual and equal: and we have shewn, how a certain set of changes of motion result from them, and have stated distinctly the whole process: we shewed, that these phenomena are similar to those of common impulsion; and we then shewed in what manner the motion of a body *gives occasion* to the exertion of various moving forces, called *elasticity, cohesion, &c.* and that this exertion must produce motions similar to those produced by repulsions *a distanti*; and, lastly, we inferred, from the perfect sameness of those results with the actual phenomena of impulsion, that those corpuscular forces are the immediate and *only* causes of the changes called impulsions, and commonly ascribed to a *peculiar* force inherent in a moving body.

49 Why does the philosopher attempt to explain gravitation, &c. by impulsion?
From a collective view of the whole, we think it clear, that the opinion that impulsion is the sole cause of motion is unwarranted. We see that the phenomena of impulsion are brought about by the *immediate* operation of pressure; and we see numberless instances of pressure, in which we cannot find the smallest trace of impulsion. It is therefore a most violent and unwarranted opinion, which ascribes to repeated unperceived impulsions all those solicitations to motion by which, or in consequence of which, the motions of bodies are affected by distant bodies, or bear an evident relation to the situation and distance of other bodies; as in the examples of planetary deflection, terrestrial gravitation, magnetical and electrical deflexions, and the like. There is nothing in the phenomenon of the pressure of gravity that seems to make impulsion more necessary or more probable than in the pressure of elasticity, whether that of a spring or of an expansive fluid. The admission of an unperceived

fluid to effect those impulsions is quite unwarranted, and the explanation is therefore unphilosophical, even although we should perceive intuitively that an atom in motion will put another into motion by hitting it. We apprehend that this cannot be affirmed with any clear perception of its truth.

50 Impulsion is supposed to be better understood, and more familiar.
On the whole, therefore, we must ascribe that contented acquiescence in the explanations of gravitation, and other attractions and repulsions, by means of impulse (if the acquiescence be not pretended), to the frequency and familiarity of impulsion, and perhaps to the personal share and interest we have in this mode of producing motion. We know that it is always objected that nothing is explained, when we say that A repels B, or that B avoids A; but we must say in return, that nothing is explained, when we say that A impels B by hitting it, or that B flies away from the stroke. Why should it not be allowed to use the term repelling power, when it is allowed to use the term impelling power, the force of impulse, inertia? All these terms only express phenomena. Does the word body express any more?

51 It is not better understood.
The maxim, that a body cannot act *where* it is not, any more than *when* it is not, is a quaint and lively expression, and therefore has considerable effect: It may be granted; for we apprehend that we understand so little about *when* and *where*, that we cannot demonstrate the affirmative or negative in either case, and that they are on a par with respect to our knowledge of them. We can have no doubt, however, of the fact, that our mind can be affected by an external object that is merely recollected. And we apprehend, that we know nothing of the difference between body and mind but what we have learned by experience. Body, for any thing that we assuredly know to the contrary, may affect, or be affected by, a distant body, as well as mind may be. It is therefore worth while to pay some farther attention to the phenomena, in order to see whether this experience is so universal and unexpected as is believed. As Mr Cotes, and many of Newton's disciples, are accused of explaining many phenomena by attraction and repulsion which their opponents affirm to be cases of impulsion; it is not impossible but that ordinary observers, who have no preconceived theories, may imagine impulsions to obtain in cases where a more accurate inspection would convince them that no impulsion has happened.

52 Enquiry into the familiarity of impulsion. Instances of a foot-ball.
When we kick away a foot-ball, we consider it as a sort of solid continuous body; yet we know that it must be filled with compressed air. It may not be impossible to have it of its round shape without being so filled: but we know that, in this condition, it would not fly away from our foot by the stroke; we should only force in the side which we kick, and the flaccid skin would lie at our feet. But when it is filled with strongly compressed air, we can form to ourselves a pretty distinct notion how it is made to move off. Our foot presses on a part of the skin: this compresses the air against the anterior part of the bag, and forces it away. If we reflect more seriously on the process, we can still conceive it clearly enough, by thinking on a row of aerial particles, reaching from the part struck by the foot to the anterior part, each touching the other, and therefore forcing the anterior part forward. The air is conceived to consist of a number

Impulsion. of little spherules in contact, each of which is compressible; and we think the operation illustrated by supposing each to be like a little vesicle or bladder. This we believe to be the usual way of conceiving the constitution of expansive fluids: But this will not agree at all with the known properties of air; for it can be easily demonstrated, that if such a collection of elastic vesicles be compressed into the half of their ordinary bulk, every vesicle will be changed from a sphere into a perfect cube, touching the adjoining cubes in every point of its six sides, and strongly pressed against them: It can also be demonstrated, that if a leaden cube of one inch be included in the box, and placed with its sides parallel to the sides of the box, and the compression be then made, all the little cubic vesicles will acquire the same position. If the box be now turned upside down, it can be demonstrated that the weight of this leaden cube will not be sufficient for overcoming the resistance of the compressed cubes. This compressed mass will not be fluid, but will require a very considerable force to press the leaden cube through it, just as we find such a force necessary for moving a body through melted glass: the particles no longer slide on each other like uncompressed spherules; each will require about half of the compressing force, in order to overcome the friction, or obstruction like friction, produced in sliding along the surface of the contiguous cubes. But we know that air remains perfectly fluid, although vastly more compressed than this. This, therefore, cannot be like the constitution or form of air. Moreover, it is well known that air has been made ten times denser than its ordinary state, and is then perfectly fluid. It has also been made a hundred times rarer, and it still remains perfectly fluid. In this state its particles must be ten times farther removed from each other than in the former state, of a thousand times greater density. Yet we know that this rare air is compressed with a force equal to the weight of a stratum of mercury $\frac{1}{3}$ d of an inch in thickness, and that if $\frac{1}{3}$ d of this pressure be removed, it will expand till it is 150 times rarer than common air; that is, there is some force which pushes the particles still farther from each other. This force evidently extends beyond the tenth particle of air that is made ten times denser than common air. Therefore the elasticity of air does not arise from the contact of particles, which are elastic like blown up bladders, but from some force which extends beyond the adjoining particles. There is no greater reason, therefore, for supposing, that the particles of air touch each other, than for supposing that the two magnets touch each other because they repel. A row of magnets floating on quicksilver, and placed with their similar poles fronting each other, and very near, will tend to separate, and they require to be held in by a stop put at each end of the canal; and if one stop be gradually withdrawn the magnets will all separate, and exhibit the general mechanical effects of a row of aerial particles separating by the removal of pressure. There seems, therefore, to be the same necessity for the operation of an intervening impelling fluid for producing this separation or elasticity of the aerial mass, as for separating the magnets.

Is very doubtful.

The result of these remarks seems to be, that the impulsion of a foot-ball is not brought about in the way that is commonly imagined, by the excitement of

corporeal pressure at the points of contact of the two foot balls. For we see it almost demonstrated, that the progressive motion of the anterior part of one of the balls has been produced without contact, or, at least, by the *intervention* of repulsions acting at a distance.—May not this obtain, even in the points in which we suppose the two balls actually to touch, in the act of impulsion?

But farther—Every person has observed the brilliant dew-drops lying on the leaves of plants. Every person acquainted with Newton's optical discoveries, must be convinced that the dew-drop is not in mathematical contact with the leaf; if it were, it could have no brilliancy. Most persons have observed the rain drops of a summer shower fall on the surface of water, and roll about for a few seconds, exhibiting the greatest brilliancy. They cannot, therefore, be in mathematical contact with the water. There must be a small distance between them, and therefore some force which keeps them asunder, and carries the weight, that is, counteracts the downward pressure of the rain-drop. We know that some insects with long legs can run about on the surface of water; and if we lift them carefully, and set them on glass, their feet do not wet it. Put a little spirit of wine into this water, and make it lukewarm, and the insect instantly sinks up to the belly, and cannot move about as before: Its feet will now wet a glass. A well-polished steel needle, even of considerable size, if perfectly clean and dry, will float on water without being wetted: It is observed to make a considerable depression on the surface of the water, just as a heavy bar of iron would make when laid on a feather-bed—the needle displaces a quantity of water equal to itself in weight, yet does not touch it, for it is not wetted. If it be previously wetted, it will not displace any water, and will not float: There is something, therefore, which keeps the water at a distance from the feet of the insect, and from the needle, exerting a certain upward pressure on them. The pressure and the reaction are indeed very small; but they would produce a very sensible motion if continued sufficiently long in proper circumstances. Here would be a production of motion, which most persons would call an impulsion—yet there would be no stroke, no contact, and therefore no true impulsion.

We now beg the reader to attend minutely to Newton's famous experiment with the object glasses of long telescopes, which we have mentioned circumstantially in the article OPTICS, *Encycl.* n^o 63—68.

When the upper glass is very thin and light, no colour appears at the point of contact: but by pressing it down with sufficient force, we shall have a black or unreflecting spot in the middle, surrounded by a silvery ring, and then by a series of rings of various colours, according to the distance between the parts of the glasses where the colours appear. Newton has counted 50 of these rings. He shews, by a careful computation from the known figure of the glasses, that the differences between the distances which exhibit these colours are all precisely equal, and that each is about $\frac{1}{8900}$ of an inch. Therefore, supposing that the glasses are in mathematical contact where the unreflecting spot appears, making one continuous mass of glass, their distance at the outermost ring must not be less than $\frac{1}{8900}$ of an inch, or $\frac{1}{89}$ of an inch. Therefore, when

53
Many cases of doubtful contact.

54
Very remarkable case of convex lenses falsely seeming to touch.

Impulsion. when one glass carries the other, without any appearance of colour at the middle, we must conclude that there is a repulsion exerted between the nearest parts, at a distance not less than $\frac{1}{15}$ of an inch, sufficient for supporting the upper glass. It requires an increase of pressure to produce the first appearance of colour; and when the pressure is still more increased, new colours appear in the middle, and the colour formerly there is now seen in a surrounding ring; these multiply continually, by new ones spreading from a central spot. A great pressure at last produces the unreflecting spot in the centre, which, unlike to all the coloured spots which had emerged in succession, is sharply defined, and never round, but ragged, and it is immediately surrounded by a bright silvery reflection. The shape of this spot depends on the figure of the surfaces; for, on turning the upper lens a little round its axis, the inequalities of the edge of the spot turn, in some degree, with it. This seemingly trifling remark will be found important by the mechanician: A still farther increase of pressure enlarges the unreflecting spot, and the dimensions of all the rings.—When the pressure is gradually withdrawn, the rings shrink in their dimensions, the unreflecting spot disappears first, and each ring in succession contracts into a spot, and vanishes. Here we have, by the way, an explanation of the brilliancy of dew-drops: they come so near, perhaps, that the nearest point reflects the silvery appearance—but they do not touch; the instant that they touch a wetted part, making one mass of transparent matter, all brilliancy is gone.

⁵⁵ **They repel each other;** Here then are incontestible proofs of a force, be its origin what it may, which keeps the glasses asunder, and even causes them to separate; which manifests itself by withstanding pressure; and therefore is, itself, a pressure, or equivalent to a pressure.—It varies in its intensity by a change of distance; but we have not been able to ascertain by what law. It must not be measured by the simple variation of the external pressure; for since we see that, even before any colour appears in the centre, the weight of the upper lens is supported, we must conclude that the glasses are exerting at least an equal force all around the circumference of the outermost ring. It is evident, that the computation of the whole force, exerted over all the coloured surface, must be difficult, even on the simplest hypothesis concerning the law of repulsion: we can only say that it increases by a diminution of distance. It is very easy to compute the increase of external pressure, which would suffice if the repelling force were equal at all distances; or if it varied according to any single power of the distances. We have tried the inverse simple, duplicate, and triplicate ratio; but the fact deviated widely from them all. The repulsion does not change nearly so much as in the simple inverse ratio of the distances, if the glasses be supposed to touch in the whole surface of the unreflecting spot. But we found, that if we suppose them separated, though at a distance equal to forty times the difference of distance at which the colours change, that is, $\frac{1}{15}$ of an inch, the pressures employed in the experiment accord pretty well with a repulsion inversely as the distance, but still with a very considerable deviation in the great pressures. In the course of a number of experiments with a favourite pair of lenses, we broke the uppermost by too

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Along a pressure. We then cut out of it, with a lapidary's hollow drill, a piece of $\frac{1}{2}$ of an inch in diameter, and perfectly round, and we squeezed it on the other by a measured pressure, till we produced a colourless spot of nearly $\frac{1}{2}$ th of an inch in diameter, with a silvery margin. Computing from this, we thought ourselves warranted to say, that not less than 800 pounds are necessary for producing a black spot of one inch square!

Now, what is the consequence of all this in the doctrine of impulsion? Surely this:—If a lump of this glass strike another lump, and put it in motion, and if the mutual pressure in the act of collision do not exceed 700 pounds on the square inch, the motion has been produced without mathematical contact, and the production can no more be called impulse than the motion of the magnet in our first experiment. The changes of motion have been the operation of moving forces, similar to the force of magnetism; and if a stream of truly impelling fluid be necessary for producing the motion of the magnet, it is equally necessary for producing the motion of the piece of glass.

It may be said here, that we cannot compare impulse and pressure. A slight blow will split a diamond which could support a house. A slight blow may therefore be enough for exciting all the pressure necessary for producing mathematical contact. We must here appeal to what every man feels on this occasion. We doubt exceedingly whether any person will think that, when one piece of glass gives another a gentle blow, and puts it into motion, with the velocity of a few inches per second, a blow which he distinctly hears, there has been exerted a pressure at all approaching to 800 pounds per square inch.—We have suspended a pair of lenses, by an apparatus so steady and firm, that they could touch only at the centres of each surface; and, having placed ourselves properly, we could see, with sufficient distinctness, the momentary appearance of the coloured spot at the instant of collision. We saw this, with the fullest confidence that it was of no considerable breadth in a moderate stroke, and that it was very sensibly broader when the stroke was more violent. We did not trust our own eye alone, but shewed it to persons ignorant of philosophy, and even to children, often without telling them what to look for, but asking them what they saw. From all the information that we could gather, none of the pressures came near to what must have been necessary for producing the black spot. This could not be mistaken: for although the outer rings are but faint, there are five or six near the centre which are abundantly vivid for affecting the eye by the momentary flash. Besides, the dimensions of the lenses, and the weight of the metal cells in which they were fixed, were such as must have caused them to split before the black spot could be produced in the centre.

These things being maturely considered, we imagine that few persons will now doubt the justice of our assertion, that in all these examples, the motions have been produced without mathematical (or rather geometrical) contact.—And we imagine also, that few will refuse granting that this is not peculiar to glass, but obtains also in the collision of other bodies. We have not thought of any method for putting this beyond doubt; but we have better reasons than mere likelihood for being of this opinion. Every one acquainted with the

Impulsion. Newtonian discoveries in optics, knows that this curious appearance of the coloured rings is the consequence of the action of transparent bodies on the rays of light, by which these are bent aside from their rectilinear course, and that this deflection takes place at a distance from the diaphanous body; a distance which the sagacity of the great philosopher has enabled us to measure. Now, it is known that metals and other opaque bodies produce the very same deflections of the rays, bending them toward themselves at one distance, and from them at other distances; in short, attracting or repelling them as the distance varies. Nothing but prepossession can hinder a person from ascribing similar effects to similar causes, and, therefore, thinking it almost certain that this mutual repulsion is not peculiar to glasses, but common to all solid bodies.

To all this we may surely add the celebrated experiment of Mr Huyghens; in which it is evident, that a smooth plate of metal attracts another, even although there be a silk fibre interposed between them. (See *Phil. Transf.* n° 86.) Is it not highly probable, that at a smaller distance the bodies repel each other? For we observe, that metals, as well as transparent bodies, attract the rays at one distance and repel them at another.

57
Impulsion is not so familiar as is believed.

Surely our readers will now grant, that the production of motion by impulsion, as distinguished from the production by action *e distanti*, is not so familiar a phenomenon as was imagined, and that it may even be said to be rare in comparison: for the instances of moderate impulses are numberless. The claim of this mode of explaining difficult phenomena by impulsion, has therefore lost much of its force; and we see much less reason for calling in the aid of invisible fluids, in order to explain the action of gravity, magnetism, and electricity.

58
Still greater doubts. Observations on a soap bubble.

But we have still more important information from the optical discovery of Newton. Let the reader turn again to OPTICS, *Encycl.* n° 65, and read the account of the phenomena exhibited by the soap-bubble. The bubble is thinner and thinner as we approach the very uppermost point of it. It also exhibits numerous rings, which vary in their colour, in the same order as in the space between the lenses. These rings come to view in the same manner. First, a coloured spot appears in the summit of the bubble; this becomes a ring, and is succeeded by another spot, as the bubble grows thinner in that part, by the gradual subsiding of the watery film. At last a black spot appears at top, well defined, but of irregular shape, surrounded by a silvery ring. This spot, when viewed very narrowly, is observed to reflect a very minute portion of light, without separating the differently colorific rays of which it consists; but it contains them all, as may be proved by viewing it through a prism. After some little time the bubble bursts.

Surely we must infer from this, that there is a certain thickness of the transparent plate which renders it unfit for the vivid reflection of light. Does it not legitimately follow from this, that the unreflecting spot between the lenses ceases to entitle us to say, that they are in contact in that place? All that we can conclude from its appearance is, that the distance still between the glasses is too small to fit the place for the vivid reflexion of light. This conclusion is indisputable. Were

it refused, we are furnished with an incontestible proof by the same bountiful hand. Newton ascribed the colours to the reflection of the plate of air between the glasses, and expected the cessation of them when the air is removed. His friend Mr Boyle had lately invented a commodious air pump. The trial was made, and young Newton found himself mistaken; for the colours still appeared, and he even thought them more brilliant. He then tried the effect of water, expecting that this would diminish their lustre. So it did; and he found that the dimensions of the rings were diminished in the proportion of 4 to 3; namely, the proportion of the refractions of glass and water. By this time Newton had discovered the curious mechanical relation between bodies and the rays of light; and his mind was wholly absorbed by the discovery, and by the revolution he was about to make in the mathematical doctrines of optics. Unfortunately for us, he did not, at that time, attend to the mighty influence which the discovery would have on the whole of mechanical philosophy, and therefore occupied himself only with such phenomena as suited his present purpose. A most important phenomenon passed unnoticed. In repeating Sir Isaac Newton's experiments, we found that the diameters of the rings decreased in the proportion of 4 to 3 only in certain circumstances. When the upper lens was pressed on the other by a heavy metal ring, so as to produce three or four coloured rings, we found that when water got between them, sometimes no colours whatever appeared; sometimes there was a ring or two, and the diameters were diminished in a much greater proportion than Newton had assigned. Well assured of the extreme nicety of all his proceedings, we were much puzzled with this discrepancy, and mentioned it to a most respectable and intelligent friend, the late Dr Reid of the university of Glasgow, a mathematician and naturalist of the first rank. He thought it not improbable that the glasses separated from each other, lifting up the weight, by attracting the water into the interstice, in the same manner that we observe wood to swell with moisture. We immediately got an apparatus which compressed the glasses by means of four screws; and now we saw Newton's proportion most strictly observed. But in prosecuting the experiment, we found that the introduction of the water *always* effaced a very small spot. This happened after precautions had been taken to prevent all separation of the glasses. As the proportion of 4 to 3 has a relation to refractive power, although we have not been able to deduce it as a necessary consequence, we nevertheless considered it as a sufficient proof that the distances of the glasses *had not changed* by introducing the water between them. Therefore we think ourselves well entitled to conclude, that the disappearance of the black spot was not owing to a separation of the glasses, which admits the water into the empty space; and we affirm, that before the entry of the water, there was room for it in the place which reflected no light; that is, that although the glasses were pressed together with a very great force, they were not in contact.

It deserves remark, that in endeavouring to produce the black spot, when water is between the glasses, we found great and unaccountable anomalies. Sometimes a moderate increase of pressure produced it, and sometimes we were not able to produce it by any pressure. Several

Remark.

Impulsion. Several lenses were broken in the trial. We are led to think that the thickness which gives the silvery reflection is much greater than the 800th part of an inch, and that it is not the same in all glasses. But we were interrupted in these experiments, and indeed in all active pursuits, by bad health, which has never permitted their renewal. The subject is of great importance to the curious mechanicians, and we earnestly recommend it to their attention. There is something very remarkable in the abrupt sensation of the coloured reflection. At a certain thickness all colours are reflected, without separation, producing the whiteness of silver. The smallest diminution of it hinders the *vivid* reflection of all colours, and then there seems to succeed a thickness which equally reflects a small proportion of all without separation. The finest polish that can be given to glass in the tool of the artist, leaves irregularities which occasion the irregular ragged figure of the spot. It is worth trying, whether smoothing the surfaces (both) by a softening heat will remove this ruggedness. If it does, without destroying the sharp termination, it will prove the abrupt passage from *esse* to *nonesse*.

The last remark to be made on this important experiment in optics is, that the distance between the glasses which is unfit for vivid reflection, cannot be determined by means of the other measurable intervals. It may be equal to many of them taken together. The same must be granted with respect to the thickness of the black spot on the top of the soap bubble. We attempted to measure this thickness by letting a drop (of a known weight) of spirit of turpentine spread on the surface of water. As it slowly enlarged in surface, it decreased in thickness, and produced, in regular order, several of the more compounded colours of the Newtonian series. But before it came to the 20th ring from the centre, it became very irregular and spotty.

⁵⁹ Contact is not proved in collision. The inference to be drawn from this combination of the two optical facts is remarkable and important. It is, that we have no authority for affirming that the changes of motion by the collision of bodies is brought about by absolute contact in any instance whatever. The glasses are not in contact where there is vivid reflection; and we have no proof that they are in contact in the black spot, however great the compression may be.

⁶⁰ Therefore impulsion cannot explain plain gravitation; It is hardly necessary now to say, that all attempts to explain gravitation, or magnetism, or electricity, or any such apparent action at a distance by the impulsions of an unseen fluid, are futile in the greatest degree. Impulsion, by absolute contact, is so far from being a familiar phenomenon, that it may justly be questioned whether we have ever observed a single instance of it. The supposition of an invisible impelling fluid is not more gratuitous than it is useless; because we have no proof that a particle of this fluid does or can come into contact with the body which we suppose impelled by it, and therefore it can give no explanation of an action that is apparently *e distanti*.

⁶¹ But impulsion may be explained by continued pressure. The general inference from the whole seems to be, that, instead of explaining pressure by impulse, we must not only derive all impulse from pressure, but must also ascribe all pressure to action from a distance; that is, to properties of matter by which its particles are moved without geometrical contact.

This collection of facts conspires, with many appear-

ances of fluid and solid bodies, to prove that even the particles of solid, or sensibly continuous bodies, are not in contact, but are held in their respective situations by the balance of forces which we are accustomed to call attractions and repulsions. The fluidity of water under very strong compressions (which have been known to compress it $\frac{1}{27}$ th of its bulk), is as inconsistent with the supposition of contact as the fluidity of air is. The shrinking of a body in all its dimensions by cold, nay, even the bending of any body, cannot be conceived without allowing that *some* of its ultimate unalterable atoms change their distances from each other. The phenomena of capillary attraction are also inexplicable, without admitting that particles act on others at a distance from them. The formation of water into drops, the coalescence of oil under water into spherical drops, or into circular spots when on the surface, shew the same thing, and are inexplicable by mere adhesion. In short, all the appearances and mutual actions of tangible matter concur in shewing, that the atoms of matter are endowed with inherent forces, which cause them to approach or to avoid each other. The opinion of Boscovich seems to be well founded; namely, that at all sensible distances, the atoms of matter tend toward each other with forces inversely as the squares of the distances, and that, in the nearest approach, they avoid each other with *insuperable* force; and, in the intermediate distances, they approach or avoid each other with forces varying and alternating by every change of distance. See the article BOSCOVICH, *Suppl.*

⁶² FROM all that has been said, we learn that physical or sensible contact differs from geometrical contact, in the same manner as physical solidity differs from that of the mathematician. Euclid speaks of cones and cylinders standing on the same base, and between the same parallels. These are not material solids, one of which would press the other out of its place. Physical contact is indicated, immediately and directly, by our sense of touch; that is, by exciting a pressure on our organ of touch when it is brought sufficiently near. It is also indicated by impulsion; which is the immediate effect of the pressure occasioned by a sufficient approximation of the body impelling to the body impelled. The impulsion is the completion of the same process that we described in the example of the magnets; but the extent of space and of time in which it is completed is so small that it escapes our observation. And we imagine it to be by contact and in an instant. We now see that it is similar to all other operations of accelerating or retarding forces, and that no change of velocity is instantaneous; but as a body, in passing from one point of space to another, passes through the intermediate space; so, in changing from one velocity to another, it passes through all the intermediate degrees without the smallest *salvus*.

And in this way is the whole doctrine of impulsion brought within the pale of dynamics, without the admission of any new principle of motion. It is merely the application of the general doctrines of dynamics to cases where every accelerating or retarding force is opposed by another that is equal and contrary. We have found that the opinion, that there is inherent in a moving body a peculiar force, by which it perseveres in motion, and puts another in motion by shifting into it,

Impulsion. is as useless as it is inconsistent with our notions of motion and of moving forces. The impelled body is moved by the insuperable repulsion exerted by all atoms of matter when brought sufficiently near. The retardation of the impelling body does not arise from an *inertia*, or resisting sluggishness of the body impelled, but because this body also repels any thing that is brought sufficiently near to it. We can have no doubt of the existence of such causes of motion. Springs, expansive fluids, cohering fibres, exhibit such active powers, without our being able to give them any other origin than the Fiat of the Almighty, or to comprehend, in any manner whatever, how they reside in the material atom. But once we admit their existence and agency, every thing else is deduced in the most simple manner imaginable, without involving us in any thing incomprehensible, or having any consequence that is inconsistent with the appearances. Whereas both of these obstructions to knowledge come in our way, when we suppose any thing analogous to force inherent in a moving body solely because it is in motion. It forces us to use the unmeaning language of force and motion passing out of one body into another; and to speak of force and velocity as things capable of division and actual separation into parts. The force of inertia is one of the bitter fruits of this misconception of things. It is amusing to see how metaphysicians of eminence, such as D'Alembert, endeavour to make its operations tally with acknowledged principles. In his celebrated work on dynamics, the most elaborate of all his performances, he explains how a body, whose mass is 1, moving with the velocity 2, must stop another body whose mass is 2, moving with the velocity 1, in the following manner: He supposes the velocity 2 to consist of two parts, and that, in the instant of collision, one of the parts destroys the motion of one half of the other body, and then the other part destroys the motion of the other half. These are words; but in vain shall we attempt to accompany them by clear conceptions. His distinction between the force of inertia and what he calls the active forces of bodies, such as the force of bodies which strike each other in opposite directions, is equally unsusceptible of clear conceptions. Active forces (says he) absorb a part of the motion; but when inertia takes part of the motion from the striking body, this motion passes wholly into the body that is stricken, none of it being absorbed or really destroyed. He demonstrates this by the equation $A \times a - x = B \times x - b$, which is a mere narration of facts, but no deduction from the nature of inertia, nor even any establishment of that nature by philosophical argument. And in attempting to give still clearer notions (being sensible that some great obscurity still hangs about it), he says, "Inertia therefore, and properly speaking, is the mean of communicating motion from one body to another. Every body resists motion; and it is by resisting that it receives it; and it receives precisely as much as it destroys in the body which acts on it." Surely almost every word of this sentence is doing violence to the common use of language. What can be more incomprehensible than that a body resists motion only when it receives it? Should a man be thought to resist being pushed out of his place when he actually allows another to displace him, and not to resist when he firmly keeps his place? All these difficulties and puzzling questions vanish when

we give over speaking of inertia as something distinguishable from the active forces or causes of motion which we find in bodies, and distinguish by the names of elasticity, cohesion, magnetism, electricity, weight, &c. and which philosophers have classed under one name, accelerating or retarding force, according as its direction chances to be the same, or the opposite to that of the motion under consideration. To suppose it a peculiar faculty by which a body maintains its condition of motion or rest, is contrary to every conception that we can annex to the words faculty, power, force. It is frivolous in the extreme to say, that snow has the faculty of continuing white or cold; or that it resists being melted because it melts, or because heat must be employed to melt it.

The only argument that we know for giving the name force to the perseverance of matter in its state of motion (or rather for ascribing this perseverance to the exertion of a peculiar faculty), which appears to deserve any attention, is one that we do not recollect to express employment of for this purpose, namely, the composition of a previous motion with the motion which a known force would produce in the body at rest. We know that if a body be moving eastward at the rate of four feet per second, and a force act on it which would impel it from a state of rest at the rate of three feet per second to the south, the body will move at the rate of five feet per second in the direction E. $36^{\circ} 52'$ S. We know also, that if a force act on this body at rest, so as to give it a motion eastward at the rate of four feet per second, and if another force act on it at the same instant, so as to give it a motion to the south at the rate of three feet per second, the body will move at the rate of five feet per second in the direction E. $36^{\circ} 52'$ S. In this instance, the body previously in motion seems to possess something equivalent to what is allowed to be a moving force. Why therefore refuse it the name? The answer is easy. The term force has been applied, by all parties, to whatever produces a change of motion, and is measured by the change which accompanies its exertion. There is some difference between the parties about the way of estimating this measure; but all agree in making, not the motion, but the change of motion, the basis of the measurement. Now we shewed, at great length, in the article DYNAMICS, that the change of motion, in every case, is that motion which, when compounded with the former motion, constitutes the new motion. Did we take the new motion itself as the characteristic and measure of the changing force, it would be different in every different previous state of the body, and would neither agree with our general notion of force, nor with the knowledge that we have of the actual pressures and other moving forces that we know. The sole reason why the previous motion is equivalent with a force is, that the only mark or knowledge that we have of a moving force is the motion which it is conceived to produce. The force is equivalent with the previous motion, because we know nothing of it but that motion; and the name that we give it, only marks some external thing to which it has an observed relation. We call it magnetism or electricity, because we observe that a magnet or an electrified body gives occasion to its appearance. We never observe the resistance of *inertia*; except in cases where we know, from other circumstances, that moving forces

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Strongest-argument for inertia is the composition of force with a previous motion.

Answered

Impulsion. forces inherent in bodies are really brought into action. The inertia of the ball which has been moved by a stroke of another, is inferred from the diminution of that other's motion. But this is occasioned precisely in the same way as the diminution of the motion of the magnet A in the first example; an event which every unprepossessed person ascribes to the repulsion of B in the opposite direction, and not to its inertia.

We trust that our readers are not displeas'd with this detail of the procedure of Nature in the phenomena of impulsion. It has been prolix; because we apprehend, that the too synoptical manner in which the laws of collision have always been delivered, leaves the mind in great obscurity concerning the connection of the events. General facts have been taken for philosophical principles and elementary truths; whereas they were deductions from the sum total of our knowledge. They were very proper logical principles for a synthetical discussion; but their previous establishment as general facts was necessary. We have established the two most general facts from which the result of every collision may be deduced with the utmost ease. The first is, that in the instant of greatest compression, the com-

mon velocity is $= \frac{Aa + Bb}{A + B}$; and we have shewn that

this is applicable to the collision of unelastic bodies. The second is, that the change in perfectly elastic bodies is double of the change in unelastic bodies. The *conservatio momentorum*, and the *conservatio virium vivarum*, are also general facts; or rather they are the same mentioned with those above, considered in another aspect. They may all be used as the principles of a synthetic treatise of impulsion; and they have been so employed. Each has its own advantages.

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Principle of smallest action.

Mr Maupertuis gives a treatise on the Communication of Motion, that is, of impulsion or collision, which has the appearance of being deduced from a new principle, which he calls the PRINCIPLE OF SMALLEST ACTION. He supposes that perfect Wisdom will accomplish every thing by the smallest expenditure of action; and he chanced to observe, in the equations employed in the common doctrine of impulsion, a quantity which is always a minimum. He chooses to consider this as the expression of the action.

His principle or axiom, deduced from the perfect wisdom of God, is thus expressed: "When any change happens in nature, the quantity of action necessary for it is the smallest possible." And then he adds,

"In mechanical changes, the quantity of action is the product of the quantity of matter in the body by the space passed over, and by the velocity of the motion." This is evidently the measure adopted long before by Leibnitz (see *Phil. Transf.* vol. xliii. p. 423, &c.), and it is equivalent to $m v^2$; because the space multiplied by the velocity is as the square of either. We refer to Dr Jurin's remarks on this passage for proof that this is by no means a just measure of action; and only observe here, that we can form no other notion of velocity than that of a certain space described in a given time. The change produced is not the actual description of a line, but the determination to that motion. It is in this respect alone that the condition of the body is changed; and therefore the product $m v$, and not $m v^2$, is the proper measure of the action. On the authority of this maxim of divine conduct, Maupertuis investi-

gates the results which will make this quantity a minimum, and asserts that these *must* be the laws of collision. Luckily this investigation is extremely simple, and very neat and perspicuous; and it gives very easy solutions. For example, the unelastic body A, moving with the velocity a , overtakes the unelastic body B, moving with the velocity b . Both move after the collision with the velocity x . This velocity is required.

To determine this, we must make $A \times a - x^2 + B \times x - b^2$ a minimum; or $A a^2 - 2 A a x + A x^2 + B x^2 - 2 B b x + B b^2$ is a minimum. Therefore $- 2 A a x + 2 A x x + 2 B x x - 2 B b x = 0$, or $2 A a + 2 B b = 2 A x + 2 B x$, and $x = \frac{A a + B b}{A + B}$; as we have already shewn it to be.

The amiable and worthy author grew more fond of his theory, when he saw what he imagined to be its influence extended to an immense variety of the operations of nature. Euler demonstrated, that the quantity called *action* by Maupertuis was a minimum in the planetary motions, and indeed in all curvilinear motions in free space. But all the while, this principle of least action is a mere whim, and the formula which is so generally found a minimum has no perceptible connection with the quantity of action. In many cases to which Maupertuis has applied it, the conclusions are in direct opposition to any notion that we can form of the economy of action. Nay, it is very disputable whether it does not, on the contrary, express the greatest want of economy; namely, a minimum of effect from a given expenditure of power. In the case of impulsion, this minimum is the mathematical result of the equality and opposition of action and reaction. Maupertuis might have pleased his fancy by saying, that it became the infinite wisdom of God to make every primary atom of matter alike; and this would have answered all his purpose.

There still remains to be considered a very material circumstance in the doctrine of impulsion, which produces certain modifications of the motions that are of mighty practical importance. We have contented ourselves with merely stating the moving force that is brought into action in the points of physical contact; but have not explained how this produces the progressive motion of every particle of the impelled body, and what motion it really does produce in the remote particles. A body, besides the general progressive motion which it receives from the blow, is commonly observed to acquire also a motion of rotation, by which it whirls round an axis. It has not been shewn, that when a body has received an impulse by a blow in a particular direction on one point, it will proceed in that direction, or in what direction it will proceed. Experience shews us, that this depends on circumstances not yet considered. The billiard player knows, that by a stroke in one direction he can make his antagonist's ball move in a direction extremely different.

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Enquiry into the distribution of impulse from the point that is struck.

These are questions of great intricacy and difficulty, and would employ volumes to treat them properly. We have already enlarged this article till we fear that we have exhausted the reader's patience, and deviated from the proportion of room justly allowable to impulsion. We must therefore limit our attention to such things only as seem elementary, and indispensably necessary.

Impulsion. necessary for a useful application of the doctrine of impulsion.

With respect to the *direction* of the motion produced by impulsion, the very example just now borrowed from billiard playing, shews that it is important, and by no means obvious. We are sorry to say, that we have nothing to offer in solution of this question that will be received by all as demonstration. It is comprehended in the following proposition, which we bring forward merely as a matter of fact.

66
Action of
bodies by
contact is
perpendi-
cular to the
touching
surface.

The direction of the stroke or pressure exerted by two bodies in physical contact, is always perpendicular to the touching surfaces. Of this truth we have a very distinct and pretty example and proof by the billiard table. If two balls A and B (fig. 2.) are laid on the table in contact, and A is smartly struck by a third ball C in any direction Cc , so that the line aA , which joins the point of contact a with the centre A, may make an obtuse angle with the line AB, joining the centres of the two balls, the ball B will always fly off in the direction ABF. The pressure on B, which produces the impulsion, is evidently exerted at the point b of contact, and the direction BF is perpendicular to the plane GbH , touching both balls in the point b . The primary stroke is at a , and acts in the direction aA , although C moved in the direction Cc . Had A been alone, it would have gone off in the direction aA produced. But the force acting in the direction aA is equivalent to the two forces ad and dA , of which dA presses the ball on B at b , and produces the motion. In like manner, another ball E, so laid that bBe is obtuse, will fly off in the direction ED, which may even be opposite to Cc . These are matters of fact; not indeed precisely so, because billiard balls are not perfectly elastic, restoring their figure with a promptitude equal to that of their compression; and also because there is a little friction, by which the point a of the ball A is dragged a little in the direction of C's motion. This may both give a twirl to A, and diminish its pressure on B. The general result, however, is abundantly agreeable to the doctrines now delivered. But we wish to shew on what properties of tangible matter this depends; and although we dare not hope for implicit belief, we expect some credit in what we shall offer.

Demonstra-
tion.

We have evident proof, that at a distance which is not unmeasurable by its minuteness, and certainly far exceeds the 900th part of an inch, bodies repel each other with very great force. This distance also far exceeds the distance between the particles, if these are discrete. Let mn (fig. 3.) be the distance at which a particle repels another, and let P be a particle situated at a less distance than mn from the surface AC of a solid body. With a radius PA, equal to mn , describe a segment of a sphere ABC, and draw PB perpendicular to AC. It is plain that every particle of matter in the segment ABC repels the particle P, and that it is not affected by any more. Let D be any such particle. It repels P in the direction DP. But there is another particle d similarly situated on the other side of PB. This will repel P with equal force in the direction dP . Therefore the two particles D and d will produce a joint repulsion in the direction BP. The like may be said of every particle and its corresponding one on the other side of PB. Therefore the joint re-

impulsion. pulsion of all the matter in the segment will have the direction BP. It is plain, that the radius of curvature of every sensible figure may be considered as immensely great in comparison of mn ; and therefore the proposition is manifest.

This is a proposition of very great importance to the artist and the engineer, as well as to the philosopher. In all the connections of engines and machines, the mutual action is regulated by this fact. The mutual pressure at the contacts of the teeth of wheels and pinions depend so much on it, that it is easy to make them of such a shape that they shall produce no force whatever that is of any service; and it requires a skilled attention to their forms to obtain the service we want. This will be considered with some care in the article MACHINE.

Having thus discovered the *direction* of the real impulsion, and that it may be very different from that of the force exerted, we proceed to consider what will be the direction and velocity of the motion, and whether it will be accompanied with any rotation.

Our readers are acquainted with the elementary me-⁶⁷chanical property of the centre of gravity. If a body whose action passes through the centre of a position of solid body, impels it without rotation. be supported at this point by a force acting vertically upwards, and equal to the united weight of every particle of matter in it, it will not only remain at rest, but will have no tendency to incline to either side; that is, the upward force balances the weight of the whole body, and the mechanical momenta of all the heavy particles balance each other, like the weights in the scales of a steelyard. That this may be the case, we know that if the weight of every particle be multiplied into the horizontal lever by which it hangs (which is a line drawn from the particle perpendicular to a vertical plane passing through the centre of gravity), the sum of all the products on one side must be equal to the sum of all the products on the other side. Therefore, if we suppose the particles all equal, and represent each by unity, the sums of all the perpendiculars themselves must be equal. How is this balancing effected? Every particle tends downwards with a certain force. It must therefore be kept up by a force *precisely* equal and opposite. This must be propagated to the particle by means of the connecting corpuscular forces. The force propagated to any particle is equal and opposite to the force acting on that particle, which it balanced; and if not balanced, it would produce a motion equal and opposite to that produced by the other force. Gravity would cause every particle to descend equally; therefore the force which, by acting on one point, excites those balancing forces on each particle, would cause them to move equally upwards. And since this is true in any attitude of the body, it follows, that a force acting in any direction through the centre of gravity, will cause all the particles to move in that direction equally; that is, without rotation.

Hence we learn, that when the direction of the stroke given to any body passes through the centre of gravity, the body will move in that direction without any rotation. If the quantity of matter, or number of equal particles in the body, be m , the moving power P will impress on each particle an accelerating force f , equal to the m th part of P. Therefore $f = \frac{P}{m}$, and $P = mf$. An accelerating force is estimated by the velocity v , which

Impulsion. which it generates by acting uniformly during some time t , or $v = ft$, and $f = \frac{v}{t}$, and $P = m \frac{v}{t}$, and $v = \frac{P}{m} t$. The symbol t may be omitted, if we reckon

every force by the velocity which it can produce in a second. Thus may all forces be compared with gravity, by taking 32 feet for the measure of gravity. Then $m v$ will express the number of pounds which give a pressure equal to the force under consideration. Thus if the force can generate the velocity 48 feet per second in 100 pounds of matter, by acting on it uniformly during a second, its pressure is equal to the weight of 150 pounds.

This is *direct* IMPULSION.

When a body A, moving with the velocity a , overtakes or meets a body B, moving with the velocity b , and the line perpendicular to their touching surfaces passes through the centres of both in the direction of their motion, all the circumstances of the collision are determined by the rules already laid down. This is called DIRECT IMPULSE; and it is this which admits the application of the simple doctrines of impulsion, deduced, as we have done it, from the action of accelerating forces. All that was said of the changes of motion produced in the magnets obtain here without any farther modification.

We may just be allowed to take notice of a curious observation of Mr Huyghens on the collision of perfectly elastic bodies. Instead of impelling the elastic ball C by the stroke of the elastic ball A, we may cause A to strike an intermediate ball B (also perfectly elastic), which is lying in contact with C. In many cases, the ball B will not stir sensibly from its place, and C alone will fly off. Nay, if a long row of equal billiard balls lie in contact, and one of the extreme balls be hit by another ball in the direction of the row, only the remote ball of the row will fly off. All this is easily seen and understood, by considering them as bodies mutually repelling, and placed at the limits of their mutual action. Or even supposing them elastic balls, at a very small distance from each other: The ball employed to strike the first comes to rest, and the stricken ball moves off with its velocity: It strikes the second ball of the row, and is brought to rest: The second strikes the third, and is brought to rest: And this goes on in succession to the last, which is the only one that can fly off. The curious observation of Mr Huyghens is, that a greater velocity will be communicated by a large ball to a small one, if we employ the intermedium of another ball of a size between the two; and that the velocity will be the greatest possible when the intermediate ball is a mean proportional (geometrical) between the two. This is also easily deduced from the similar attention to the action of the accelerating forces, or from the supposition of successive impulses. From this it also follows that a greater velocity will be produced by the intervention of two, three, or more; mean proportionals.

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Oblique IMPULSION.

But the direction of the stroke may not be the same with that of the motion. This is called OBLIQUE IMPULSE. The cases of oblique collisions are extremely different, according to the directions of the motions; and the results are, in many of them, far from being obvious. But we have not room for a particular treatment of them. We shall therefore avail ourselves of

some of the general facts mentioned above, by means of which we may reduce all the varieties to some easy cases. The most serviceable general facts are: 1. That the actions of bodies on each other depend on their relative motions; and, 2. That the motion of the common centre is not changed by the collision. These enable us to reduce all to the case of a body in motion striking another at rest. We have only to determine their relative motion by the proposition in DYNAMICS, n^o 67. and then to superadd the common motion, which changes the relative into the true motions. Thus if two bodies A and B (fig. 4.) meet in D, describing the lines AD, BD, the collision is the same as if B had remained at rest, and A had come against it with the motion AB. In the mean time, the common centre of position has described CD. If the bodies are unelastic, they remain united, and proceed in the line CD produced toward E, and their common velocity will be represented by DE, equal to CD, if AD and BD represented their initial velocities. If the bodies are elastic, they separate again, and they separate from the common centre in the opposite direction, and with the same velocities with which they approached it. Therefore draw $a E b$ parallel to ACB, and make $E a$, $E b$ equal to CA and CB, and then $D a$ and $D b$ are the paths and velocities of the bodies. All this is abundantly plain, and is a necessary deduction from the general principle, that the motion of the centre is not affected by any equal and opposite forces which connect the bodies of a system.

But this great simplicity is not sufficient for ascertaining the results of collision which occur in many of the most important cases. It not only supposes that AD and ED are exactly proportional to the velocities of A and B, but also that they meet, so that the plane of mutual contact is perpendicular to the line AB, and that the stroke on each is directed to its centre. These circumstances will not always be combined, even in the case of spherical bodies. The consequence will be, that although the motion of the centre remains the same, that of the bodies may sometimes be different. We must therefore give a general proposition, which will, with a little trouble, enable the reader to determine all the motions which can take place, whether progressive or rotative.

69
Often accompanied by rotation.

Let the body A (fig. 5.), moving with the velocity V, in the direction AD, strike the body B at rest. Let F be the point of mutual contact, and $b F H$ a plane touching both bodies in F. Draw AFP perpendicular to this tangent plane, and through G, the centre of position of B, draw PGC perpendicular to FP, and GI parallel to FP. Let C, in the line PG, be the spontaneous centre of conversion (ROTATION, *Encycl.* n^o 77. &c.), corresponding to the point of percussion F. Join CF. Let the direction cut the tangent plane in H, and PF in A; and let AH represent the velocity V.

70
General theorem.

The impulse is made at the point F, in the direction AF or FP, and the centre of position of the body B will advance in the direction GI, parallel to FP, the direction of the effective impulse. But because this does not pass through the centre G, the body will advance, and will also turn round an axis passing through G, perpendicular to the plane of the lines GP, PF, and the spontaneous axis of conversion will pass through some.

Impulsion.

Impulsion. some point C of the line PG, and will also be perpendicular to the same plane. All this has been demonstrated in the article ROTATION, n^o 94, &c. Complete the parallelogram AFHE. It is plain, that the motion AH is equivalent to AE and AF. By the motion AE, A only slides along the surface of B without pressing it, or causing any tendency to motion in that direction, except perhaps a little arising from friction. It is by the motion AF alone that the impulse is made.

71
Efficient
velocity.

Therefore let v be $= V \times \frac{AF}{AH}$; and then $A \times v$ may be called the *efficient impulse* of the body A in the present circumstances, and v the *efficient velocity*. This will be diminished by the collision. Let x be the unknown velocity remaining in A after the collision, or rather in the instant of the greatest compression and common motion of the touching points of A and B, estimated in the direction FP. The effective momentum lost by A must therefore be $A \times v - x$: but the same must be gained by B, and its centre G must move in the direction GI, parallel to FP, with this momentum; and therefore with the velocity $\frac{A \times v - x}{B}$. That this

may be the case, the point of percussion F must yield with the velocity x , because the bodies are in contact. But because C is the spontaneous axis of conversion, every particle is *beginning* to describe an arch of a circle round this axis. Therefore F is beginning to move in the direction Fg, perpendicular to the momentary radius vector CF. Let Fg be a very minute arch, described in a moment of time. Draw gf perpendicular to FP. Then Ff is the motion Fg reduced to the direction FP, and will express the yielding of B in the direction of the impulse, while G describes a space equal to $\frac{A \times v - x}{B}$, and A describes a space x . Therefore Fg will express x . Let Pp be the space described in the same time that Fg is described. Draw pC, cutting GK in the point I. GI is the yielding of the body B to the impulse, and must therefore be equal to $\frac{A \times v - x}{B}$.

The triangles Ffg and CPF are similar; for the angle CFP is the complement of Ffg to a right angle: It is also the complement of PCF to a right angle. Therefore Fg : Ff = FC : CP. But Fg : Pp = FC : CP; because the little arches Fg, Pp have the same angle at C. Therefore Pp = Ff, = x . It is plain, that CG : CP = GI : Pp. Therefore CG : CP = $\frac{A \times v - x}{B} : x$, and $x = \frac{A \times v - x \times CP}{B \times CG}$, or x

$$= v \times \frac{A \times CP}{B \times CG} - x \times \frac{A \times CP}{B \times CG}; \text{ wherefore}$$

$$x \times B \times CG + x \times A \times CP = v \times A \times CP, \text{ and}$$

$$x \times B \times CG + A \times CP = v \times A \times CP, \text{ and}$$

$$x = v \times \frac{A \times CP}{B \times CG + A \times CP}, \text{ = the velocity remain-}$$

72
Unelastic
bodies may
separate.

ing in A, estimated in the direction FP. And u , the velocity with which G will advance, is $\frac{CG}{CP}$; for CP : CG = Pp : GI, = $x : u$. It is evident that A will change its direction by the collision: For in the instant of greatest compression, it was react-

ed on by a force = $A \times v - x$ in the direction FA. This must be compounded with $A \times V$, in the direction AH, in order to obtain the new motion of A; or it may be found by compounding x , which is retained by A, with FH, which has suffered no change by the collision. The bodies will therefore separate, although they be unelastic: If they are elastic, we must double these changes on each. If B was also in motion before the collision, the motion of A must be resolved into two, one of which is equal and parallel to the motion of B: the other must be employed as we have employed the motion AH.

Expressions still more general may be obtained for x and u ; namely, by taking the formulæ for the centres of conversion and percussion (ROTATION, n^o 96, 99.)

$$CG = \frac{\int p r^2}{B \times GP}, \text{ and } CP = \frac{\int p r^2 + B \times CP^2}{B \times GP},$$

where p stands for a particle of matter, and r for its distance from an axis passing through G perpendicularly to the plain of the lines GP and PF. In this way

$$\text{we obtain } x = v \frac{A \cdot \int p r^2 + A \cdot B \cdot GP^2}{A + B \cdot \int p r^2 + A \cdot B \cdot GP^2}$$

It is plain from this proposition, that the progressive motion of the body depends, not only on the momentum of the impelling body, but also on the place where the other is struck: For even although the original momentum of A be the same, and the obliquity of the stroke, making v the same, and the body (and consequently $\int p r^2$) also remain the same, we see that x and u depend on the ratio of CP to CG. Now C and P are always on opposite sides of G: Consequently, by removing the direction FP of the impulsion farther from G, we diminish CG and increase CP; and there-

fore increase the value of $x = v \frac{A \cdot CP}{B \cdot CG + A \cdot CP}$; and consequently diminish the value of $A \times v - x$, to which $B \times u$ is equal. The greatest momentum of B is produced when the direction of the impulse passes through G, and no rotation is produced. Indeed we are led, by a sort of common sense, to expect this.

This investigation is by no means a piece of mere speculative curiosity. It is the solution of the greatest problem in practical mechanics. It is in this way that we must proceed in computing the actions of the wind and water on the sails and hull of a ship. Were it not that many circumstances concur in determining several of the preparatory steps, it is evident that the task must be almost impracticable. But the pressure and its direction are generally determined by experiment, without the trouble of computation; and we are seldom solicitous about the subsequent motion of the wind or water.

There is another question in impulsion which is of the first practical importance—namely, when the impulse is exerted on the parts of a machine, where the body struck is not at liberty to yield freely to the stroke, but must slide along some solid path, or turn round some axis, or take some other constrained motion. The operations of most engines depend on this. The operation of wedges, axes, and many cutting and piercing instruments, and the penetration of piles, impelled

Impulsion.

73
Change of
progressive
motion
greatest
when the
direction of
the effective
stroke
passes thro'
the centre.

74
Importance
of this theo-
ry to sea-
manship,
&c.

75
Impulsion
on bodies
confined
to particu-
lar paths.

Fig 1.

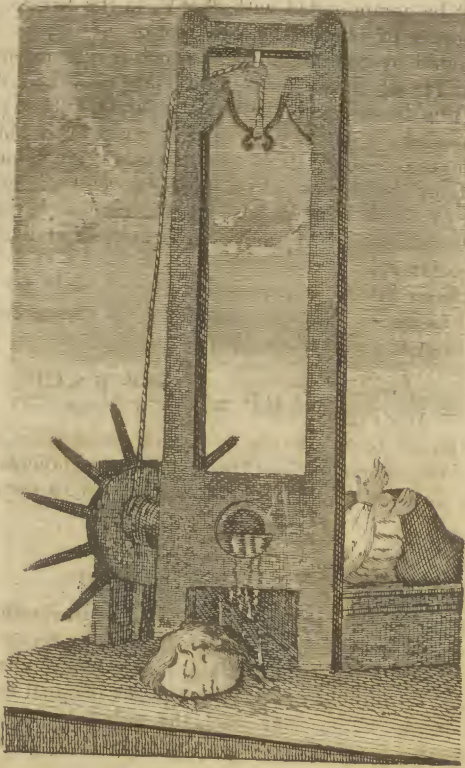


Fig 2.



IMPULSION

Fig 1.



Fig 3.

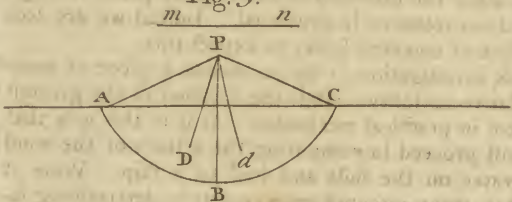


Fig 5.

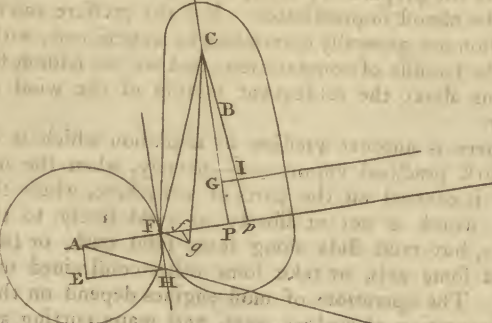


Fig 2.

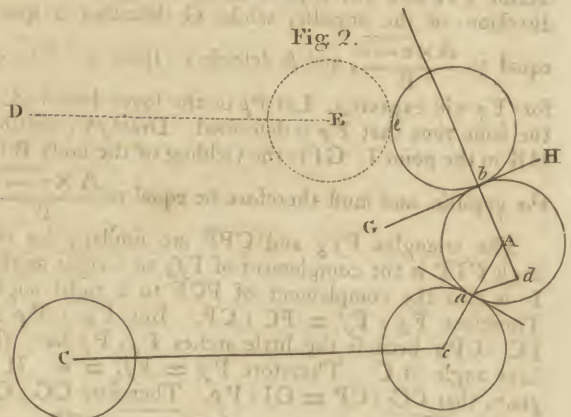
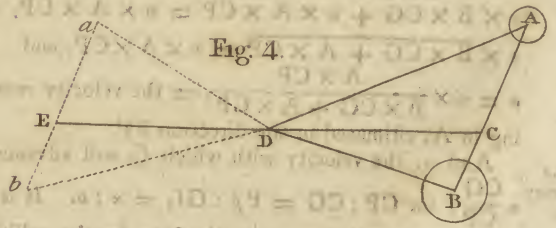
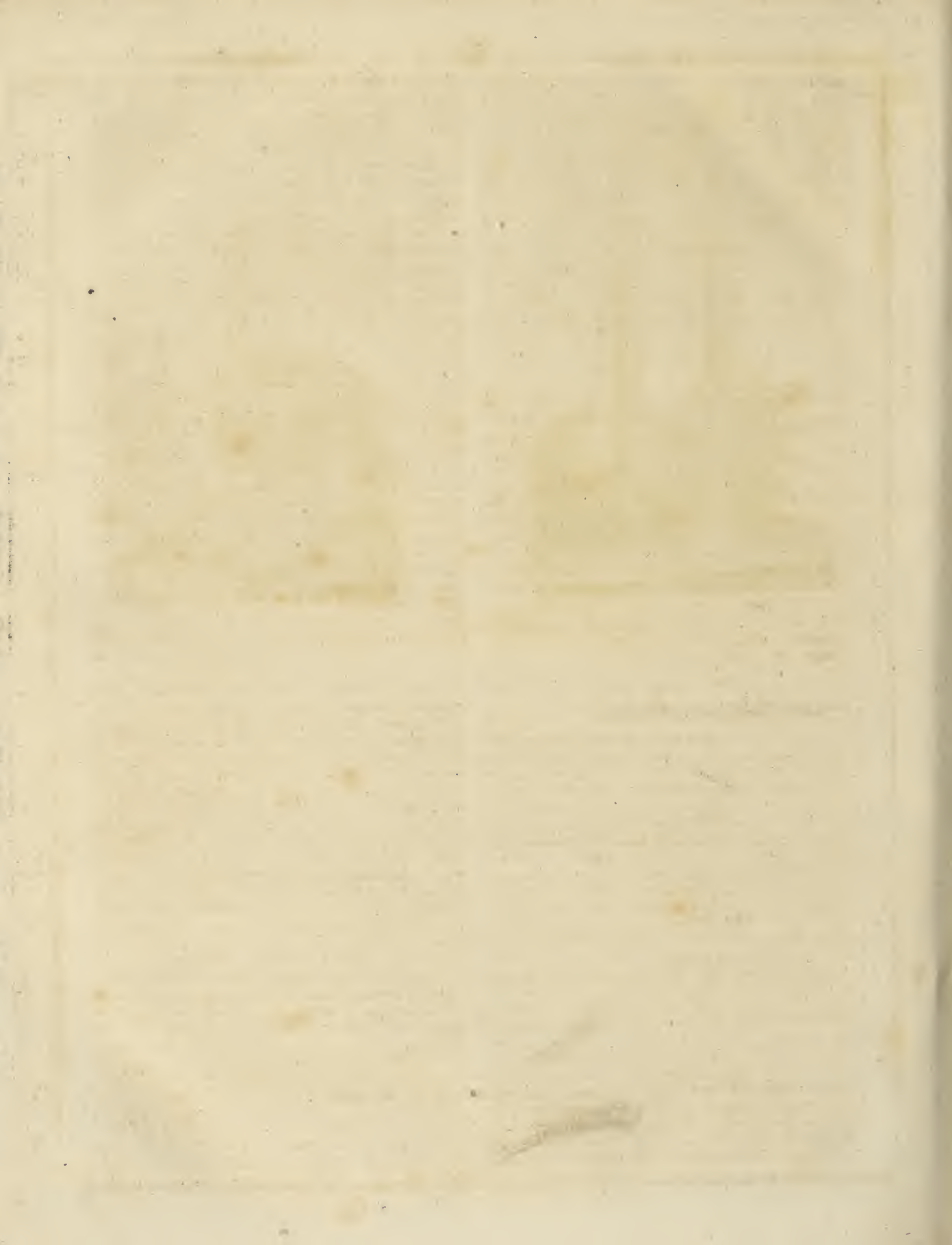


Fig 4.





Impulsion. pelled by a rammer, are all ascertained by the same doctrines. But the particular applications can scarcely be elucidated by any classification that occurs to us, the circumstances of the case making such great difference in the result, both in kind and degree. For example, in the simplest case that occurs, the driving of piles, the penetration of the pile depends, in the first place, on the momentum of the rammer. If the mass of the pile be neglected, the penetration through a uniformly resisting substance will be as the square of the velocity of the rammer (*DYNAMICS, Suppl. n° 95.*), and its absolute quantity may be determined from a knowledge of the proportion of the weight of the rammer to the resistance of the earth. But when we consider that we have to put in motion the whole matter of the pile, we learn that a great diminution of the effect must take place. We still can compute what this must be, because we have the same momentum, with a velocity diminished in a certain proportion of the sum of the matter in the rammer and pile, to that in the rammer alone.—Another defalcation arises from friction, which continually increases as the pile goes deeper;—and a still greater defalcation proceeds from the nature of the pile. If it is a piece of very dry straight grained fir, it is very elastic, and acquires almost a double velocity from the stroke of a rammer of cast iron. If it is moist and soft, especially if it is oak, or other timber of an undulated fibre, it does not acquire so great velocity, and the penetration is very much diminished. It is probable that a pile, headed with moist cork, could not be driven at all. The writer of this article found a remarkable effect of the elasticity in the process of boring limestone. When the boring bit was made entirely of steel, and tempered through its whole length to a hard spring temper, the workman bored three inches, in the same time that another bored two inches with a bit made of soft iron; and he would never use any but steel bits, if they could be hindered from chipping by the hammer (which must also be of tempered steel throughout). This has hitherto baffled many attempts. A pretty large round head, like a marlin spike, has succeeded best: but even this cracks after some days use. The improvement is richly worth attention; for the workman is delighted by feeling the hammer rise in his hand after every stroke, and says that the work is not so hard by half. *N. B.* The stone cutters at Lisbon and Oporto use iron mallets.

76 Impulsion on machines. The case of impulsion made on part of a machine moveable round an axis has been considered in the article *ROTATION, Encycl. n° 72*; where x is shewn to

$$be = v \times \frac{A \cdot CP^2}{\int p r^2 + A \cdot CP^2}$$

But, in this formula, r denotes the distance of p from the point C , and not from

G . $\int p r^2$ in this formula, is $B \cdot CG \cdot CP$; whereas, in the formula for a free body, where r is the distance of a particle from G , $\int p r^2$ is $B \cdot CG \cdot GP$.

In the practical consideration of this question, the reader will do well to consider the whole of that article with attention. Many circumstances occur, which make a proper choice of the point of impulse, and the direction of the tangent plane, of the greatest consequence to the good performance of the machine; and there is

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nothing in which the scientific knowledge of the engineer is of more essential service to him. An engineer of great practice, and a sagacious combining mind, collects his general observations, and stores them up as rules of future practice. But it is seldom that he possesses them with that distinctness and confidence that can enable him to communicate his knowledge to others, or even secure himself against all mistakes; whereas a moderate acquaintance with these *elements* of real mechanics, may be applied with safety on all occasions, because arithmetical computations, when rightly made, afford the most certain of all results.

There is a circumstance which greatly affects the performance of machines which are actuated by impulses, namely, the yielding and bending of the parts. When the moving power acts by repeated small impulsions, it may sometimes be entirely consumed, without producing any effect whatever at the remote working point of the machine; and the engineer, who founds his constructions on the elementary theories to be had in most treatises of mechanics, will often be miserably disappointed. In the usual theories, even as delivered by writers of eminence, it is asserted, that the smallest impulse will start the greatest weight. But since impulse is only a continued pressure, and requires time for the transmission of its effect through the parts of a yielding solid, it is plain that the motion of the impelling body may be extinguished before it has produced compression enough for exciting the forces which are to raise the remote parts of a heavy body from the ground. What blow with a hammer could start a feather bed? Much oftener may we expect, that a blow, given to one arm of a long lever, will be consumed in bending the whole of its length, so as to bring the remote end into action. Therefore great stiffness, and perfect elasticity, both in the moving parts and in the points of support, are necessary for transmitting the full, or even a considerable part, of the power of the impelling body. Perhaps not the half of the blow given by the wipers of a great forge or tilting mill to the shank of the hammer is transmitted in the *proper* instant of time to the hammer-head. The hammer, while it is tossed up by the blow, is quivering as it flies. Should it reach the spring above it in the time of its downward vibration, it will not be returned with such force as if it had hit the spring a moment before or after. A quarter of an inch will produce a great effect in such cases. It is found, that the minute impulses given to the pallets of a clock or watch lose much of their force by the imperfect elasticity of the pendulum or balance. We must therefore make all the parts which transmit the blow to the regulating mass of matter as continuous, hard, elastic, and stiff, as possible. The performance of ruby pallets is very sensibly weakened by putting oil on the face of them, especially in the detached scapements, which act partly by impulse. A wheel of hard tempered steel, working on a dry ruby pallet, excels all others. The intelligent engineer, seeing that, after all his care, much impulsion is unavoidably lost, will avoid employing a first mover which acts in a subfultory manner, and will substitute one of continued pressure when it is in his power. This is one chief cause of the great superiority of overshot water wheels above the undershot.

We can now understand how it happens that Galileo, Mersennus, and others, could compare the impulse

Impulsion. given by a falling body with the pressure of a weight in the opposite scale of a balance, and can see the reason of the immense differences, yet accompanied by a sort of regularity, in the results of the experiments. Galileo, Merfennus, and Riccioli, found them to be proofs that the forces of moving bodies are as their velocities; because the heights from which the body fell were as the squares of the weights started from the ground. Gravesande found the same thing as long as he held the same opinion; but when he adopted the Leibnitzian measure, he found many faults in the apparatus employed in his former illustrations, and altered it, till he obtained results agreeable to his new creed. But any one who examines with attention all that passes in the bending of the apparatus, and takes into account the mass of matter which must be displaced before the opposite arm rises so far as to detach the spring which gives indication of the magnitude of the stroke, must see that the agreement is purely accidental, and may be procured for any theory we please (see *Gravesande's Nat. Phil.* translated by Desaguliers, vol. i. p. 241. &c.) The proposition, n° 95, DYNAMICS, suffices for explaining every thing that can happen in such experiments. And it will shew us, that although the motion of impulsion is produced by pressure alone, yet impulse is incomparable with mere pressure: It is not infinitely greater, but disparate. A weight (which is a pressure) bends a spring to a certain degree, and will derange to a certain degree the fibres of a body on which it presses, before it be balanced. The same weight, falling on this spring from the *smallest* height, will bend it farther, and may crush or shiver to pieces the body which would have carried it for ever. We shall make some further remarks on this subject, of great practical importance, under the word PERCUSSION.

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CONCLU
SION.

THE method which we have pursued in considering the doctrines of impulsion, differs considerably from that which has generally been followed; but we trust that it will not be found the less instructive. Although the reader should not adopt our decided opinion, that we have no proof of pure impulsion ever being observed, and that all the phenomena which go by that name are really the effects of pressures, analogous to gravity, he perceives that our opinion does not lead to any general laws of impulsion that are different from those which are acknowledged by all. We differ only, by exhibiting the internal procedure by which they are *unquestionably* produced in a vast number of cases, and which takes place in all that we have seen, in some degree. Our method has undoubtedly this advantage, that it requires no principle but one, namely, that accelerating forces are to be estimated by the acceleration which they produce. Even this may be considered, not as a principle, but merely as a definition—We get rid of all the obscurity and perplexity that result from the introduction of inertia, considered

as a power—a power of doing nothing; and we are freed from the unphilosophical fiction (adopted by all the abettors of that doctrine, and even by many others) of conceiving the space, in which motions are performed, and bodies act, to be carried along with the bodies in it.—This furnishes, indeed, in some cases, a familiar way of conceiving the thing, by supposing the experiments to be made in a ship under sail, and by appealing to the fact, that all our experiments are made on the surface of a globe that is moving with a very great velocity. But it is an absurdity in philosophy, and, when minutely or argumentatively used, it does not free us from one complication of action; for, before we can make use of this substitution, we must demonstrate, that the actions depend on the relative motions only: And this, when demonstrated, *obliges* us to measure forces by the velocity which they produce.

As no part of mechanical philosophy has been so much debated about as impulsion, it will surely be agreeable to our readers to have a notice of the different treatises which have been published on the subject:

Galilei Opera, T. I. 957. II. 479, &c.

Jo. Wallisii Tractatus de Percussione. Oxon. 1669.

Chr. Hugenius de Motu Corporum ex Percussione. Op. II. 73.

Traité de la Percussion des Corps, par Mariotte, Op. I. 1.

Hypothesis Physica Nova, qua phenomenorum causæ ab unico quodam universali motu in nostro globo supposito repetuntur. Auct. G. G. Leibnitzio. Moguntiae 1671.—Leibn. Op. T. II. p. II. 3.

Ejusdem Theoria Motus Abstracti. Ibid. 35.

Hermannii Phoronomia. Amst. 1716.

Discours sur les Loix de la Communication de Mouvement, par Jean Bernoulli, Paris, 1727. Jo. Bern. Oper. III.

Dynamique de D'Alembert.

Euleri Theoria Corporum solidorum seu rigidorum, 1765.

Borelli (Alphons) de Percussione.

See also M'Laurin's Fluxions, and his Account of Newton's Philosophy, for his Dissertation crowned by the Acad. des Sciences at Paris.—Also Dr Jurin's elaborate dissertations in the Phil. Trans. N° 479.—Also Gravesande's Nat. Philosophy, where there is a most laborious collection of experiments and reasonings; all of which receive a complete explanation by the 39th Prop. Princip. Newtoni I. or our n° 95. DYNAMICS. There are also many very acute philosophical observations in Lambert's *Gedanken über die Grundlehren des Gleichgewichts, und der Bewegung.* in the second part of his *Gebrauch der Mathematik.*—Also, in the works of Kaestner, Hamberger, and Busch. Mufchenbroeck also treats the subject at great length, but not very judiciously. We do not know any work which treats it with such perspicuous brevity as M'Laurin's Account of Newton's Philosophy.

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